Enantioselective Synthesis of (–)-Acetylapoaranotin

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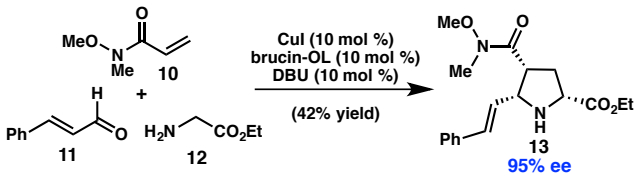
Supporting Information 1 (Experimental Procedures):

Table of Contents

General Considerations. Unless otherwise stated, reactions were performed under a nitrogen atmosphere using freshly dried solvents. Tetrahydrofuran (THF), methylene chloride (CH_2Cl_2), acetonitrile (MeCN), dimethylformamide (DMF), and toluene (PhMe) were dried by passing through activated alumina columns. Triethylamine (Et_3N), and *N,N*-diisopropylethylamine (DIPEA) were distilled over calcium hydride prior to use. Unless otherwise stated, chemicals and reagents were used as received. All reactions were monitored by thin-layer chromatography using EMD/Merck silica gel 60 F254 pre-coated plates (0.25 mm) and were visualized by UV, *p*-anisaldehyde, or $KMnO_4$ staining. Flash column chromatography was performed as described by Still et al.[1] using silica gel (partical size 0.032-0.063) purchased from Silicycle. Optical rotations were measured on a Jasco P-2000 polarimeter using a 100 mm path-length cell at 589 nm. ^1H and ^{13}C NMR spectra were recorded on a Varian 400 MR (at 400 MHz and 101 MHz, respectively), a Bruker 400 equipped with a cryoprobe (at 400 MHz and 101 MHz, respectively), a Varian Inova 500 (at 500 MHz and 126 MHz, respectively), or a Varian Inova 600 (at 600 MHz and 150 MHz, respectively), and are reported relative to internal $CHCl_3$ (^1H, δ = 7.26), $CHDCl_2$ (^1H, δ = 5.32), CD_2HOD (^1H, δ = 3.31), MeCN-*d2* (^1H, δ = 1.94), or DMSO-*d5* (^1H, δ = 2.50), and $CDCl_3$ (^{13}C, δ = 77.0), CD_2Cl_2 (^{13}C, δ = 54.0), CD_3OD (^{13}C, δ = 49.0), MeCN-*d3* (^{13}C, δ = 118.3), or DMSO-*d6* (^{13}C, δ = 40.0). Data for ^1H NMR spectra are reported as follows: chemical shift (δ ppm) (multiplicity, coupling constant (Hz), integration). Multiplicity and qualifier abbreviations are as follows: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad, app = apparent. IR spectra were recorded on a Perkin Elmer Paragon 1000 spectrometer and are reported in frequency of absorption (cm^{-1}). HRMS were acquired using an Agilent 6200 Series TOF with an Agilent G1978A Multimode source in electrospray ionization (ESI), atmospheric pressure chemical ionization (APCI), or mixed (MM) ionization mode. Analytical chiral HPLC was performed with an Agilent 1100 Series HPLC utilizing Chiralpak AD or Chiralcel OD-H columns (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd with visualization at 254 nm. Preparative HPLC was performed with an Agilent 1100 Series HPLC utilizing an Agilent Eclipse XDB-C18 5µm column (9.4 x 250 mm) or an Agilent Zorbax RX-SIL 5µm column (9.4 x 250 mm). Melting points were determined using a Büchi B-545 capillary melting point apparatus and the values reported are uncorrected.

Synthetic Procedures

Preparation of pyrrolidine 13



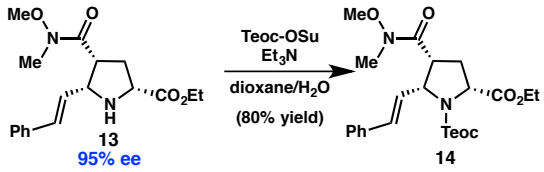
Preparation of ethyl glycinate: ethyl glycinate hydrochloride salt (3.0 g, 21.5 mmol) was suspended in 50 mL of CH_2Cl_2 and KOH (1.32 g, 1.2 equiv) in 100 mL H_2O was added with vigorous stirring. Saponification of the ethyl ester occurred readily, so it was important to accurately measure KOH. The layers were separated, and the aqueous layer was further extracted with CH_2Cl_2 (2 x 50 mL), dried over Na_2SO_4, and concentrated to yield 1.75 g (79% yield) of the free amine **12** (slightly volatile under high vacuum). The amine was used immediately to avoid dimerization.

Generation of imine: The free amine **12** (1.75 g, 17.0 mmol, 1.1 equiv) was dissolved in 35 mL $CHCl_3$. Silica gel (4.5 g, 0.3 g SiO_2 per mmol substrate) was added and the resulting suspension was cooled to 0 °C while open to the atmosphere. *Trans*-cinnamaldehyde **11** (1.9 mL, 15.0 mmol, 1.0 equiv) was added dropwise and the reaction was left to stir at 0 °C for an additional 3 hours, during which it turned from colorless to light yellow. The silica gel was removed via filtration and rinsed with 50 mL $CHCl_3$, and the resulting imine solution was used immediately.

(1,3)-Dipolar cycloaddition reaction: A round-bottom flasked was charged with CuI (287 mg, 1.5 mmol, 10 mol %), brucin-OL (647 mg, 1.5 mmol, 10 mol %), and 35 mL of $CHCl_3$. The resulting suspension was stirred at 0 °C under air. After a five-minute prestir, DBU (225 µL, 1.5 mmol, 10 mol %) was added and the solution was stirred vigorously for twenty minutes during which the solution went from cloudy brown to dark green. *N*-methoxy-*N*-methylacrylamide **10** (2.6 g, 22.6 mmol, 1.5 equiv) was then added, followed by the solution of imine (precooled to 0 °C and transferred *via* cannula over 5 min). The reaction was kept at 0 °C for 5 hours and then allowed to warm to room temperature over 7 hours. The reaction mixture was concentrated to half the volume and loaded directly onto SiO_2 and subjected to flash chromatography (50 : 45 : 5 hexanes : ethyl acetate : methanol) to afford 2.12 g (42% yield, 6.38 mmol) of **13** as a light yellow oil. The enantiomeric excess was determined to be 95% by chiral HPLC analysis (OD, 1 mL/min, 15% IPA in hexanes, λ = 254 nm): t_R(minor) = 13.3 min, t_R(major) = 24.7 min. $[\alpha]_D^{25}$ = +152° (*c* = 0.90, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 – 7.29 (m, 2H), 7.29 – 7.22 (m, 2H), 7.21 – 7.16 (m, 1H), 6.53 (d, *J* = 15.7 Hz, 1H), 6.10 (dd, *J* = 15.7, 8.3 Hz, 1H), 4.22 (qd, *J* = 7.1, 3.2 Hz, 2H), 4.12 (t, *J* = 7.9 Hz, 1H), 3.86 (t, *J* = 8.4 Hz, 1H), 3.65 (s, 3H), 3.59 (q, *J* = 7.7 Hz, 1H), 3.05 (s, 3H), 2.56 (s, 1H), 2.45 – 2.28 (m, 2H), 1.28 (t, *J* = 7.1 Hz, 3H); ^{13}C (126 MHz, $CDCl_3$) δ 173.7, 173.4, 136.6, 131.9, 128.3, 127.5, 127.4, 126.4, 63.6, 61.3, 61.0, 59.8, 45.3, 33.2, 32.2, 14.1; FTIR (NaCl/thin film) 3340, 3298, 3057, 3024, 2979,

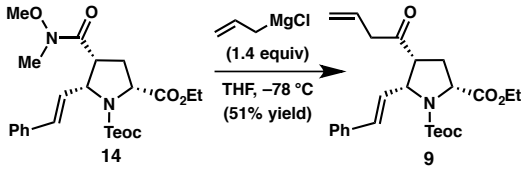
2937, 2902, 1955, 1882, 1735, 1654, 1599, 1493, 1448, 1388, 1321, 1255, 1197, 1108, 1073, 1056, 1028, 1008, 969, 901, 861, 834, 786, 754 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{24}N_2O_4$ $[M+H]^+$ 333.1809, found 333.1817.

Preparation of Teoc-pyrrolidine 14



Pyrrolidine **13** (3.17 g, 9.54 mmol, 1.0 equiv) was suspended in H_2O (24 mL) and 1,4-dioxane (24 mL). Triethylamine (2.66 mL, 19.07 mmol, 2.0 equiv) was added followed by Teoc-OSu (3.71 g, 14.31 mmol, 1.5 equiv). The resulting solution was allowed to stir for 26 hours at room temperature. The solution was acidified with 60 mL 1M HCl then extracted with EtOAc (3 x 50 mL). The combined organic extracts were dried over $MgSO_4$ and concentrated to yield a light orange oil. Flash chromatography (10% to 60% EtOAc in hexanes) afforded Teoc-pyrrolidine **14**, as a thick yellow oil (3.89 g, 8.16 mmol, 86% yield). $[\alpha]_D^{25}$ = +101° (*c* = 0.64, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 7.38 – 7.29 (m, 4H), 7.29 – 7.21 (m, 1H), 6.70 (dd, *J* = 15.8, 1.1 Hz, 1H), 6.05 (dd, *J* = 15.8, 7.6 Hz, 1H), 4.92 (t, *J* = 7.8 Hz, 1H), 4.30 (dd, *J* = 10.3, 7.6 Hz, 1H), 4.21 (qd, *J* = 7.1, 1.0 Hz, 2H), 4.18 – 4.12 (m, 2H), 3.75 (s, 3H), 3.61 (dt, *J* = 12.2, 7.4 Hz, 1H), 3.08 (s, 3H), 2.46 (q, *J* = 12.0 Hz, 1H), 2.33 (dt, *J* = 13.0, 7.2 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 0.97 (dd, *J* = 8.8, 7.5 Hz, 2H), 0.03 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, compound exists as a 1:1 mixture of rotamers) δ 173.8, 173.5, 171.3, 155.8, 155.0, 137.8, 132.8, 129.6, 128.6, 127.7, 127.3, 127.2, 64.3, 64.2, 62.3, 62.0, 61.8, 61.7, 61.2, 59.7, 59.4, 46.6, 45.9, 32.8, 31.6, 30.6, 18.4, 18.3, 14.6, -1.4, -1.5; FTIR (NaCl, thin film): 2953, 2900, 1747, 1700, 1668, 1404, 1345, 1282, 1250, 1186, 1112, 1038, 1012, 961, 860, 838, 756, 694 cm^{-1}; HRMS (MM) calc'd for $C_{22}H_{33}N_2O_6Si$ $[M-C_2H_4+H]^+$ 449.2102, found 449.2110 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

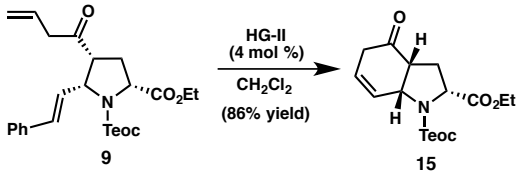
Preparation of diene 9



Weinreb amide **14** (2.37 g, 4.97 mmol, 1.0 equiv) was dissolved in dry THF (42 mL) under N_2 and the solution was cooled to –78 °C. A solution of allyl Grignard (0.85M in THF, diluted with THF from commercially available reagent; 8.2 mL, 6.96 mmol, 1.4 equiv) was added slowly over the course of 4 hours using a syringe pump at –78 °C. Following the addition, the reaction was allowed to stir for another 10 minutes before being

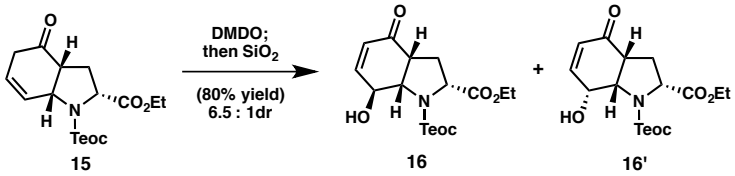
quenched with 30 mL of AcOH/THF/H_2O (1:1:1) and warmed to room temperature. The reaction was then carefully basified with saturated $NaHCO_3$ solution until gas evolution ceased. The aqueous layer was then extracted with EtOAc (3 x 150 mL). The combined organic layers were washed with brine (200 mL) and dried over Na_2SO_4, filtered, and concentrated to give a yellow oil. Flash chromatography (5% to 30% EtOAc in hexanes) afforded diene **9**, as a yellow oil (1.15 g, 2.51 mmol, 51% yield). $[\alpha]_D^{25}$ = –8° (*c* = 0.495, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 7.39 – 7.29 (m, 4H), 7.29 – 7.21 (m, 1H), 6.77 (dd, *J* = 15.9, 0.9 Hz, 1H), 6.01 (ddd, *J* = 15.7, 8.1, 0.8 Hz, 1H), 5.95 – 5.77 (m, 1H), 5.16 – 5.10 (m, 1H), 5.12 – 5.07 (m, 1H), 4.97 (t, *J* = 8.0 Hz, 1H), 4.30 (dd, *J* = 9.8, 8.0 Hz, 1H), 4.20 (qt, *J* = 7.2, 1.2 Hz, 2H), 4.17 – 4.10 (m, 2H), 3.55 (dt, *J* = 11.6, 7.5 Hz, 1H), 3.26 (dt, *J* = 6.9, 1.3 Hz, 2H), 2.48 – 2.23 (m, 2H), 1.27 (td, *J* = 7.1, 0.7 Hz, 3H), 1.06 – 0.88 (m, 2H), 0.03 (d, *J* = 0.8 Hz, 9H); ^{13}C NMR (101 MHz, CD_3CN, compound exists as a 1:1 mixture of rotamers) δ 205.5, 205.4, 173.6, 173.3, 155.6, 154.8, 137.5, 133.74, 133.68, 131.6, 129.7, 128.9, 128.8, 127.3, 126.6, 126.5, 119.1, 64.4, 64.3, 62.1, 62.0, 61.9, 61.7, 59.8, 59.5, 54.7, 54.1, 48.2, 30.5, 29.5, 18.4, 14.6, -1.47, -1.52; FTIR (NaCl, thin film): 3082, 3060, 3024, 2981, 2952, 2899, 1749, 1702, 1450, 1408, 1371, 1344, 1285, 1250, 1185, 1168, 1110, 1038, 962, 924, 860, 837, 751, 694 cm^{-1}; HRMS (MM) calc'd for $C_{23}H_{32}NO_5Si$ $[M–C_2H_4+H]^+$ 430.2044, found 430.2053 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

Preparation of ketone 15



To a 500 mL flame-dried flask was added diene **9** (1.15 g, 2.51 mmol, 1.0 equiv) and CH_2Cl_2 (250 mL). Hoveyda-Grubbs II catalyst (63 mg, 0.10 mmol, 4 mol %) was added and the resulting light green solution was allowed to stir at room temperature for 4 hours. The reaction was then quenched with DMSO (380 µL, 50 equiv) and stirred for another 22 hours. The reaction mixture was filtered through a silica gel plug, eluting with EtOAc, and the filtrate was concentrated to give a light brown oil. Flash chromatography (5% to 25% EtOAc in hexanes) afforded ketone **15**, as a light brown oil (761 mg, 2.15 mmol, 86% yield). $[\alpha]_D^{25}$ = –117° (*c* = 0.63, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 65 °C) δ 6.04 (dq, *J* = 10.2, 2.5 Hz, 1H), 5.80 (dtd, *J* = 10.2, 3.7, 1.6 Hz, 1H), 4.79 (dt, *J* = 7.6, 2.3 Hz, 1H), 4.32 (dd, *J* = 8.3, 7.1 Hz, 1H), 4.24 – 4.15 (m, 2H), 4.12 (qd, *J* = 7.1, 1.1 Hz, 2H), 3.05 (q, *J* = 8.0 Hz, 1H), 2.99 – 2.80 (m, 2H), 2.45 – 2.26 (m, 2H), 1.23 (t, *J* = 7.1 Hz, 3H), 1.00 (t, *J* = 8.3 Hz, 2H), 0.05 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, 65 °C) δ 207.5, 173.3, 155.8, 128.1, 124.4, 64.7, 62.2, 61.2, 60.2, 51.0, 38.2, 32.8, 19.0, 14.8, -1.0; FTIR (NaCl, thin film): 3042, 2953, 2899, 1749, 1703, 1454, 1412, 1350, 1249, 1186, 1112, 1033, 988, 964, 946, 860, 838, 769, 695 cm^{-1}; HRMS (MM) calc'd for $C_{15}H_{24}NO_5Si$ $[M–C_2H_4+H]^+$ 326.1418, found 326.1419 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

Preparation of enone 16

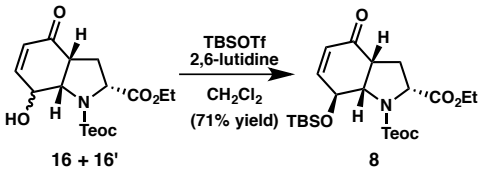


To ketone **15** (761 mg, 2.15 mmol, 1.0 equiv) in a 200 mL round-bottom flask was added freshly prepared DMDO acetone solution (0.0905 M, 48 mL, 4.30 mmol, 2.0 equiv) and the resulting solution was allowed to stir at room temperature for 90 minutes (the reaction was monitored by taking ^{1}H NMR spectra of the reaction aliquots). The reaction was then concentrated and put under high vacuum for 90 minutes to remove the residual solvent. The crude material was then dissolved in toluene (215 mL) and mixed with silica gel (17.2 g). The resulting mixture was heated to 50 °C for 1 hour and cooled to room temperature. The mixture was filtered through a silica gel plug, eluting with EtOAc, and the filtrate was concentrated to give a light brown oil. Flash chromatography (5% to 40% EtOAc in hexanes) afforded enones **16** and **16'**, (6.5 : 1 mixture of diastereomers by ^{1}H NMR, where **16** is the major diastereomer), as a thick colorless oil (630 mg, 1.71 mmol, 80% yield). The mixture of diastereomers was carried through the next reaction. Analytically pure products were isolated using preparative reverse phase HPLC (50% to 60% CH_3CN in H_2O over 10 minutes, t_R(**16**) = 8.0-8.7 min, t_R(**16'**) = 9.5-10.0 min).

*Major diastereomer **16**.* $[\alpha]_D^{25}$ = –23° (*c* = 1.925, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.85 (dd, *J* = 10.4, 2.1 Hz, 1H), 6.00 (dd, *J* = 10.4, 2.5 Hz, 1H), 4.91 (s, 1H), 4.78 (dt, *J* = 7.2, 2.3 Hz, 1H), 4.38 (dd, *J* = 8.6, 7.3 Hz, 1H), 4.33 (dd, *J* = 9.8, 7.6 Hz, 1H), 4.25 – 4.12 (m, 4H), 3.04 (dt, *J* = 12.8, 8.2 Hz, 1H), 2.65 (dt, *J* = 12.7, 7.6 Hz, 1H), 1.95 (td, *J* = 12.8, 9.7 Hz, 1H), 1.26 (t, *J* = 7.1 Hz, 3H), 1.01 – 0.88 (m, 2H), 0.02 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 195.4, 171.7, 156.8, 150.5, 126.9, 70.0, 65.2, 65.1, 61.6, 59.2, 45.6, 32.8, 17.7, 14.1, -1.6; FTIR (NaCl, thin film): 3413, 2953, 2899, 1744, 1676, 1457, 1420, 1374, 1350, 1304, 1250, 1215, 1188, 1166, 1118, 1069, 1032, 960, 861, 839, 770, 695 cm^{-1}; HRMS (MM) calc'd for $C_{15}H_{24}NO_6Si$ $[M–C_2H_4+H]^+$ 342.1367, found 342.1378 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

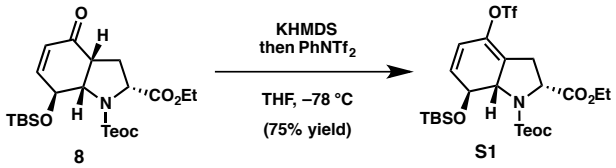
*Minor diastereomer **16'**.* $[\alpha]_D^{25}$ = –58° (*c* = 0.405, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 7.08 (dd, *J* = 10.0, 5.9 Hz, 1H), 6.10 (d, *J* = 10.0 Hz, 1H), 4.70 – 4.56 (m, 1H), 4.39 (dd, *J* = 9.5, 7.9 Hz, 1H), 4.37 – 4.32 (m, 1H), 4.27 – 4.15 (m, 5H), 3.08 (dt, *J* = 12.0, 8.3 Hz, 1H), 2.62 (dt, *J* = 12.2, 8.2 Hz, 1H), 2.13 (app q, *J* = 11.6 Hz, 1H), 1.26 (t, *J* = 7.1 Hz, 3H), 1.10 – 0.90 (m, 2H), 0.06 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, compound exists as a mixture of rotamers) δ 198.7, 175.2, 155.7, 148.0, 147.2, 132.3, 131.9, 64.9, 63.2, 62.7, 61.6, 60.8, 60.4, 47.1, 46.7, 34.5, 33.9, 18.3, 14.4, -1.5; FTIR (NaCl, thin film): 3445, 2953, 2900, 1698, 1404, 1377, 1348, 1303, 1251, 1203, 1177, 1114, 1065, 1030, 999, 975, 942, 899, 853, 838, 769, 696 cm^{-1}; HRMS (MM) calc'd for $C_{15}H_{24}NO_6Si$ $[M–C_2H_4+H]^+$ 342.1367, found 342.1376 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

Preparation of TBS ether 8



A flame-dried 50 mL round-bottom flask was charged with enone **16**/**16'** (462 mg, 1.25 mmol, 1.0 equiv; as a 6.5 : 1 mixture of **16**/**16'**) and dry CH_2Cl_2 (12 mL), which was cooled to –78 °C. 2,6-Lutidine (0.72 mL, 6.25 mmol, 5.0 equiv) was added, followed by slow addition of TBSOTf (0.57 mL, 2.50 mmol, 2.0 equiv). The resulting clear solution was allow to stir at –78 °C for 90 minutes. The reaction was quenched with pH 7 buffer (15 mL) and warmed to room temperature. The mixture was separated and the aqueous layer was extracted with EtOAc (3 x 20 mL). The combined organic layers were washed with brine (50 mL), dried over Na_2SO_4, filtered, and concentrated to give a colorless oil (extended drying under high vacuum removed the residual 2,6-lutidine, improving subsequent purification). Flash chromatography (1% to 18% EtOAc in hexanes) afforded TBS ether **8** as a single diastereomer, which was a colorless oil (425 mg, 0.825 mmol, 71% yield). $[\alpha]_D^{25}$ = +49° (*c* = 0.650, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 6.79 (dd, *J* = 10.3, 2.8 Hz, 1H), 5.95 – 5.89 (m, 1H), 4.86 (br s, 1H), 4.43 – 4.37 (m, 2H), 4.22 (app q, *J* = 8.8 Hz, 1H), 4.18 – 4.04 (m, 3H), 2.96 (dt, *J* = 10.1, 7.5 Hz, 1H), 2.52 (dt, *J* = 12.9, 8.2 Hz, 1H), 2.11 (q, *J* = 10.5 Hz, 1H), 1.23 (t, *J* = 7.1 Hz, 3H), 1.00 (t, *J* = 8.5 Hz, 2H), 0.95 (s, 9H), 0.18 (s, 3H), 0.17 (s, 3H), 0.04 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, 60 °C) δ 197.7, 173.6, 156.8, 151.9, 129.0, 69.4, 66.3, 64.8, 62.3, 61.3, 48.1, 33.4, 26.6, 19.0, 18.9, 14.9, -1.1, -4.0, -4.2; FTIR (NaCl, thin film): 2953, 2929, 2896, 2856, 1748, 1701, 1682, 1462, 1405, 1375, 1340, 1319, 1289, 1250, 1211, 1187, 1155, 1099, 1058, 985, 956, 939, 862, 829, 779 cm^{-1}; HRMS (MM) calc'd for $C_{21}H_{38}NO_6Si_2$ $[M–C_2H_4+H]^+$ 456.2232, found 456.2231 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

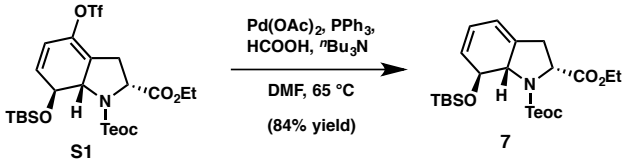
Preparation of vinyl triflate S1[2]



A flame-dried 50 mL round-bottom flask was charged with TBS ether **8** (200 mg, 0.41 mmol, 1.0 equiv), dry THF (7.4 mL) and cooled to –78 °C. A solution of KHMDS (0.5M in toluene, 0.9 mL, 0.45 mmol, 1.1 equiv) was slowly added to the flask. The reaction solution turned dark red upon addition. The solution was stirred for 5 minutes before the addition of a THF solution of $PhNTf_2$ (162 mg, 0.45 mmol, 1.1 equiv; prepared by dissolving 180 mg in 1 mL THF and used 0.9 mL). The mixture was stirred for 2 hours before quenching with 1% NaOH solution (10 mL) and was warmed to room temperature. The mixture was separated and the organic layer was

washed with 1% NaOH solution (10 mL). The aqueous layer was extracted with diethyl ether (3 x 20 mL). The combined organic layers were washed with brine (50 mL), dried over Na_2SO_4, filtered, and concentrated to give a light yellow oil. Flash chromatography (1% to 8% EtOAc in hexanes) afforded vinyl triflate **S1**, as a colorless oil (191 mg, 0.31 mmol, 75% yield; to avoid the decomposition of **S3**, this intermediate was isolated and used immediately). $[\alpha]_D^{25}$ = +14° (*c* = 0.69, CH_2Cl_2); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 5.96 (d, *J* = 10.2 Hz, 1H), 5.87 (dd, *J* = 10.2, 2.3 Hz, 1H), 5.06 – 4.90 (m, 3H), 4.28 (ddd, *J* = 10.9, 9.3, 7.4 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 2H), 4.09 (ddd, *J* = 10.8, 9.2, 7.1 Hz, 1H), 3.00 – 2.76 (m, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.03 (ddd, *J* = 9.3, 7.0, 1.8 Hz, 2H), 0.93 (s, 9H), 0.09 (s, 3H), 0.07 (s, 3H), 0.05 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, 60 °C) δ 172.8, 157.1, 140.7, 138.6, 132.1, 124.6, 121.7, 121.5, 115.1, 75.6, 67.8, 65.2, 64.6, 62.7, 31.9, 26.7, 19.1, 18.8, 14.8, -1.1, -4.0, -4.4 (one of the quartet of -CF_3 ^{13}C NMR peaks is masked under the solvent peak; the other quartet peaks are underlined); FTIR (NaCl, thin film): 3426, 2954, 2930, 2898, 2857, 1750, 1722, 1709, 1423, 1403, 1361, 1334, 1295, 1251, 1213, 1142, 1104, 1037, 973, 943, 894, 839, 779, 769, 693, 619 cm^{-1}; HRMS (MM) calc'd for $C_{22}H_{37}F_3NO_8SSi_2$ $[M–C_2H_4+H]^+$ 588.1725, found 588.1744 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

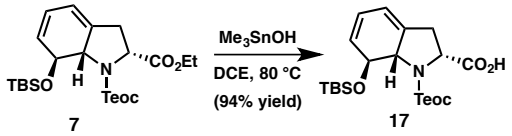
Preparation of cyclic diene 7[2]



A flame-dried 50 mL round-bottom flask was charged with vinyl triflate **S1** (260 mg, 0.42 mmol, 1.0 equiv), $Pd(OAc)_2$ (19 mg, 0.084 mmol, 20 mol %), and PPh_3 (44 mg, 0.169 mmol, 40 mol %). The system was purged with N_2 and charged with dry DMF (8 mL), ^{n}Bu_3N (0.50 mL, 2.11 mmol, 5.0 equiv), and formic acid (48 μL, 1.27 mmol, 3.0 equiv). The resulting yellow, clear solution was heated to 65 °C for 15 minutes, at which point the reaction turned black. It was then diluted with EtOAc (25 mL) and washed with 1M HCl (25 mL), H_2O (25 mL) and brine (25 mL). The aqueous layers were each extracted with ether (20 mL). The combined organic layers were then dried over Na_2SO_4, filtered, and concentrated to give a brown oil. Flash chromatography (1% to 10% EtOAc in hexanes) afforded cyclic diene **7**, as a light yellow oil (165 mg, 0.35 mmol, 84% yield). $[\alpha]_D^{25}$ = +55° (*c* = 1.43, $CHCl_3$); ^{1}H NMR (400 MHz, CD_3CN, 60 °C) δ 5.88 – 5.81 (m, 1H), 5.81 – 5.73 (m, 1H), 5.65 (d, *J* = 9.6 Hz, 1H), 4.87 – 4.76 (m, 2H), 4.74 – 4.64 (m, 1H), 4.33 – 4.23 (m, 1H), 4.17 (qd, *J* = 7.1, 1.0 Hz, 2H), 4.07 (ddd, *J* = 10.8, 9.0, 7.3 Hz, 1H), 2.93 – 2.80 (m, 1H), 2.63 (d, *J* = 15.9 Hz, 1H), 1.26 (t, *J* = 7.2 Hz, 3H), 1.02 (ddd, *J* = 8.8, 7.1, 1.1 Hz, 2H), 0.93 (s, 9H), 0.08 (s, 3H), 0.07 (s, 3H), 0.05 (s, 9H); ^{13}C NMR (101 MHz, CD_3CN, 60 °C) δ 173.5, 157.6, 142.0, 135.3, 125.6, 119.1, 76.7, 66.7, 64.7, 64.3, 62.3, 35.1, 26.8, 19.2, 18.9, 15.0, -1.0, -3.8, -4.3; FTIR (NaCl, thin film): 3049, 2954, 2928, 2897, 2855, 1750, 1722, 1699, 1472, 1398, 1361, 1329, 1290,

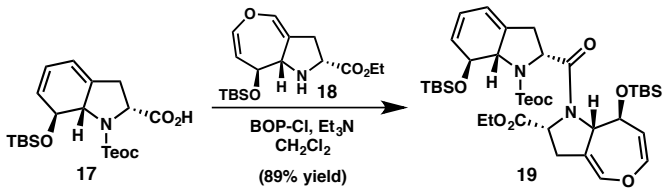
1250, 1204, 1180, 1105, 1031, 958, 839, 776, 701, 670 cm^{-1}; HRMS (MM) calc'd for $C_{21}H_{38}NO_5Si_2$ [M–C_2H_4+H]$^+$ 440.2283, found 440.2298 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

Preparation of carboxylic acid 17



Cyclic diene **7** (31.5 mg, 0.067 mmol, 1.0 equiv) was transferred to a 1-dram vial, to which was added Me_3SnOH (122 mg, 0.673 mmol, 10 equiv) and dry DCE (1.3 mL). The vial was sealed with a Teflon cap and heated to 80 °C for 26 hours. It was then cooled to room temperature and quenched with pH 2.5 buffer (2 mL). The mixture was separated and the aqueous layer was then extracted with EtOAc (6 x 2 mL). Combined organic layer was washed with brine (15 mL). It was then dried over Na_2SO_4, filtered, and concentrated to give a light brown oil. Flash chromatography (1% to 6% MeOH in CH_2Cl_2) afforded carboxylic acid **17**, as a light brown oil (27.6 mg, 0.063 mmol, 94% yield). $[\alpha]_D^{25}$ = +44° (*c* = 0.59, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$, 45 °C) δ 5.87 – 5.77 (m, 2H), 5.69 (d, *J* = 9.5 Hz, 1H), 4.93 – 4.79 (m, 1H), 4.72 (d, *J* = 14.4 Hz, 1H), 4.58 (d, *J* = 14.4 Hz, 1H), 4.38 (d, *J* = 10.3 Hz, 1H), 4.09 (q, *J* = 9.5 Hz, 1H), 2.99 – 2.77 (m, 2H), 1.07 (dd, *J* = 9.6, 7.9 Hz, 2H), 0.90 (s, 9H), 0.04 (s, 3H), 0.04 (s, 12H); ^{13}C NMR (101 MHz, $CDCl_3$, 45 °C) δ 175.1, 157.6, 139.4, 134.6, 124.3, 118.7, 75.4, 65.0, 64.6, 62.8, 32.8, 26.0, 18.2, 18.0, -1.5, -4.6, -5.1; FTIR (NaCl, thin film): 3121, 3051, 2954, 2928, 2897, 2856, 1747, 1699, 1471, 1418, 1360, 1335, 1250, 1178, 1107, 1042, 1020, 970, 957, 862, 838, 776, 700, 667, 627 cm^{-1}; HRMS (MM) calc'd for $C_{19}H_{34}NO_5Si_2$ [M–C_2H_4+H]$^+$ 412.1970, found 412.1977 (detected fragment has undergone elimination of ethylene from the Teoc protecting group).

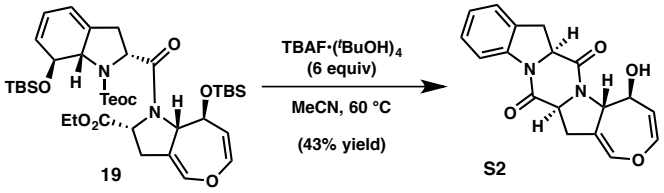
Preparation of dipeptide 19



To a 1-dram vial was transferred carboxylic acid **17** (27.6 mg, 0.063 mmol, 1.0 equiv) and amine **18**[3] (23.4 mg, 0.069 mmol, 1.1 equiv), using CH_2Cl_2, and the mixture of starting materials was co-evaporated with benzene (1 mL). The mixture of starting materials was then dissolved in dry CH_2Cl_2 (1.2 mL), followed by the addition of Et_3N (88 µL, 0.628 mmol, 10 equiv) and BOP-Cl (80 mg, 0.314 mmol, 5 equiv). The reaction mixture was allowed to stir at room temperature for 24 hours and quenched with saturated $NaHCO_3$ (2 mL). The mixture was extracted with EtOAc (5 x 2 mL). The combined organic layers were washed with brine (10 mL), dried over

Na_2SO_4, filtered through a silica gel plug, and concentrated to give a mixture of white solid and light brown oil. Flash chromatography (1% to 5% EtOAc in hexanes) afforded dipeptide **19**, as a colorless oil (42.2 mg, 0.055 mmol, 89% yield). $[\alpha]_D^{25}$ = +38° (*c* = 0.865, $CHCl_3$); ^{1}H NMR δ (400 MHz, CD_3CN) 6.48 (td, *J* = 2.5, 1.2 Hz, 1H), 6.23 (dd, *J* = 8.2, 2.2 Hz, 1H), 5.87 – 5.80 (m, 1H), 5.72 (qd, *J* = 2.2, 1.3 Hz, 1H), 5.67 (br s, 1H), 5.57 (d, *J* = 9.6 Hz, 1H), 5.47 (dd, *J* = 5.7, 3.0 Hz, 1H), 4.83 (dd, *J* = 10.1, 1.8 Hz, 1H), 4.79 (dd, *J* = 8.2, 1.9 Hz, 1H), 4.75 – 4.72 (m, 2H), 4.46 (dt, *J* = 7.9, 2.1 Hz, 1H), 4.28 – 4.18 (m, 1H), 4.13 (qd, *J* = 7.1, 0.7 Hz, 2H), 3.98 (dt, *J* = 16.4, 8.5 Hz, 1H), 2.87 (dddd, *J* = 15.8, 10.1, 2.6, 1.6 Hz, 1H), 2.68 (dq, *J* = 15.8, 1.6 Hz, 1H), 2.65 – 2.60 (m, 2H), 1.23 (t, *J* = 7.1 Hz, 3H), 1.03 – 0.98 (m, 2H), 0.93 (s, 9H), 0.85 (s, 9H), 0.15 (s, 3H), 0.06 (s, 3H), 0.02 (s, 9H), -0.08 (s, 3H), -0.10 (s, 3H); ^{13}C NMR δ (101 MHz, CD_3CN, 50 °C) 173.5, 173.3, 158.1, 145.7, 139.8, 137.3, 134.5, 126.2, 117.4, 116.9, 112.0, 75.8, 72.4, 67.7, 65.1, 64.2, 62.4, 61.7, 58.8, 35.4, 33.2, 26.8, 26.6, 19.1, 19.1, 19.0, 14.8, -1.2, -2.8, -4.1, -4.6, -5.1; FTIR (NaCl, thin film): 3049, 3014, 2954, 2929, 2895, 2856, 1747, 1717, 1694, 1652, 1472, 1463, 1428, 1393, 1348, 1329, 1315, 1250, 1213, 1179, 1139, 1094, 1039, 974, 949, 860, 837, 780, 756, 701, 667, 632 cm^{-1}; HRMS (MM) calc'd for $C_{38}H_{64}N_2O_8Si_3Na$ $[M+Na]^+$ 783.3863, found 783.3866.

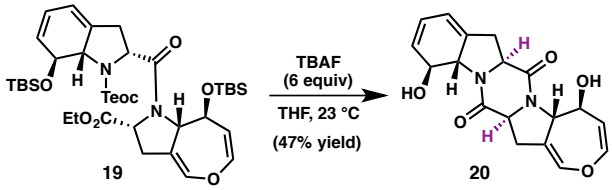
Preparation of DKP S2 (undesired reaction pathway)



A 5 mL Schlenk tube was charged with TBAF•(^{t}BuOH)$_4$ (4.8 mg, 0.009 mmol, 6 equiv)[4], followed by addition of dipeptide **19** (1.1 mg, 0.0014 mmol, 1.0 equiv) as a CH_3CN solution (0.16 mL). The resulting solution was degassed using the freeze-pump-thaw technique. The vessel was sealed and the solution frozen by submersion in a bath of liquid N_2. The vessel was then placed under vacuum for ca. five minutes before once again being sealed and allowed to thaw under static vacuum by removal from the liquid N_2 bath. This procedure was repeated three times before the head-space was finally backfilled with N_2, the vessel sealed, and the solution heated to 70 °C with stirring. After 1.5 hours, the reaction mixture was cooled to room temperature, diluted with saturated Na_2SO_4 solution, and extracted with EtOAc (5 x 0.5 mL). Each organic fraction was passed individually through a plug of SiO_2, which was then rinsed with excess EtOAc. The combined organic filtrates were concentrated *in vacuo* to provide the crude product, which was purified by preparative TLC (50% EtOAc in hexanes) afforded alcohol **S2**, as a white solid (0.2 mg, 0.0006 mmol, 43% yield). $[\alpha]_D^{25}$ = –331° (*c* = 0.355, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 7.9 Hz, 1H), 7.27 (t, *J* = 8.0 Hz, 2H), 7.13 (td, *J* = 7.5, 1.1 Hz, 1H), 6.53 (q, *J* = 2.0 Hz, 1H), 6.20 (dd, *J* = 8.2, 2.3 Hz, 1H), 5.41 (d, *J* = 4.5 Hz, 1H), 5.07 – 4.98 (m, 1H), 4.92 (dd, *J* = 8.0, 2.1 Hz, 1H), 4.87 (dd, *J* = 8.2, 2.0 Hz, 1H), 4.50 (td, *J* = 9.0, 1.7 Hz, 1H), 4.40 (ddt, *J* = 8.2, 4.3, 2.1 Hz, 1H), 3.61 (ddt, *J* = 16.6, 10.0, 1.2 Hz, 1H), 3.41 (dd, *J* = 16.5, 10.1 Hz, 1H), 3.06 (dt, *J* = 9.0, 1.7 Hz, 2H); ^{13}C

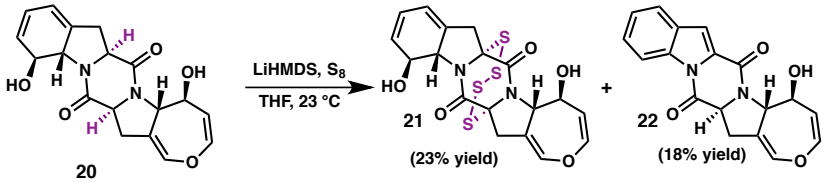
NMR (101 MHz, $CDCl_3$) δ 168.3, 163.6, 140.4, 138.5, 137.7, 129.7, 128.0, 125.4, 125.0, 116.2, 110.4, 110.3, 71.5, 64.4, 61.0, 58.8, 33.2, 30.7; FTIR (NaCl, thin film): 3338, 3013, 2928, 2859, 1668, 1602, 1486, 1464, 1418, 1328, 1287, 1248, 1192, 1129, 1077, 1047, 978, 916, 860, 821, 755, 665, 625 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{15}N_2O_3$ $[M–OH]^+$ 307.1077, found 307.1081 (detected fragment has undergone loss of hydroxyl anion).

Preparation of diol 20



In a 1-dram vial, dipeptide **19** (15.3 mg, 0.020 mmol, 1.0 equiv) was co-evaporated with benzene (1 mL) and the vial was purged with argon. THF (1.9 mL) was added into the vial, followed by dropwise addition of TBAF (1M solution in THF, 120 µL, 0.12 mmol, 6 equiv). The resulting clear orange solution was allowed to stir at room temperature for 7 hours before being quenched with saturated Na_2SO_4 solution, and extracted with EtOAc (7 x 2 mL). Each organic fraction was passed individually through a plug of SiO_2, which was rinsed with excess EtOAc. The combined organic filtrates were then concentrated *in vacuo* to provide the crude product. Flash chromatography (10% to 95% EtOAc in hexanes) afforded diol **20**, as a white solid (3.2 mg, 0.009 mmol, 47% yield). $[\alpha]_D^{25}$ = –456° (*c* = 0.17, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.53 (td, *J* = 2.5, 1.1 Hz, 1H), 6.19 (dd, *J* = 8.2, 2.3 Hz, 1H), 5.93 (s, 1H), 5.92 – 5.84 (m, 2H), 5.79 – 5.72 (m, 1H), 5.20 (d, *J* = 4.6 Hz, 1H), 4.90 (dd, *J* = 7.9, 2.1 Hz, 1H), 4.87 (dd, *J* = 8.2, 1.9 Hz, 1H), 4.81 – 4.73 (m, 1H), 4.73 – 4.63 (m, 2H), 4.45 (ddd, *J* = 10.2, 7.5, 2.2 Hz, 1H), 4.41 – 4.34 (m, 1H), 3.05 – 2.96 (m, 2H), 2.92 (ddt, *J* = 15.2, 10.7, 2.2 Hz, 1H), 2.81 (dddt, *J* = 17.8, 12.1, 2.5, 1.3 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.8, 167.7, 138.4, 137.8, 132.6, 130.2, 123.0, 119.1, 110.4, 109.6, 73.5, 71.3, 68.2, 64.2, 62.3, 58.0, 33.5, 32.6; FTIR (NaCl, thin film): 3253, 3048, 2923, 2851, 2787, 1667, 1622, 1441, 1386, 1350, 1284, 1267, 1250, 1236, 1206, 1187, 1132, 1084, 1047, 1002, 852, 823, 750, 736, 708, 629 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{17}N_2O_4$ $[M–OH]^+$ 325.1183, found 325.1194 (detected fragment has undergone loss of hydroxyl anion).

Preparation of tetrasulfide 21

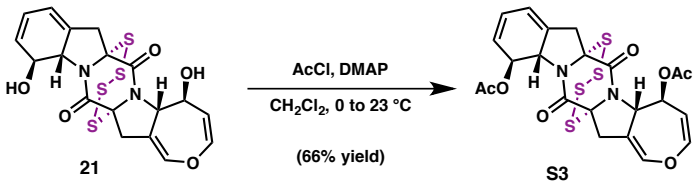


To a suspension of S_8 (20 mg, 0.078 mmol, 9.2 equiv) in THF (0.34 mL) at 0 °C under argon was added LiHMDS (1 M in THF, 340 µL, 0.34 mmol, 40 equiv) dropwise over 2 min. This solution was stirred for an

additional 5 min, and half of the solution was transferred using syringe dropwise to a THF solution (0.17 mL) of diol **20** (2.9 mg, 0.0085 mmol, 1.0 equiv) over 2 min. The reaction mixture was allowed to stir for 4 hours and quenched with saturated $NaHCO_3$ (2 mL), and then the mixture was extracted with EtOAc (4 x 2 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4, filtered, and concentrated to give a yellow solid. Preparative TLC (60% EtOAc in hexanes) afforded tetrasulfide **21**, as a yellow solid (0.9 mg, 0.0019 mmol, 23% yield). $[\alpha]_D^{25}$ = –375° (*c* = 0.045, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.54 (t, *J* = 2.3 Hz, 1H), 6.21 (dd, *J* = 8.2, 2.4 Hz, 1H), 5.98 – 5.91 (m, 1H), 5.92 – 5.86 (m, 1H), 5.79 (d, *J* = 9.8 Hz, 1H), 5.33 (s, 1H), 5.08 – 4.98 (m, 2H), 4.93 (dd, *J* = 8.3, 2.0 Hz, 1H), 4.78 (d, *J* = 13.3 Hz, 1H), 4.60 (d, *J* = 4.5 Hz, 1H), 4.46 (td, *J* = 4.9, 2.3 Hz, 1H), 3.30 – 3.19 (m, 2H), 3.03 (dd, *J* = 16.1, 3.1 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.3, 169.4, 138.9, 138.0, 131.0, 129.5, 122.9, 121.2, 110.4, 106.4, 78.1, 74.5, 72.7, 71.5, 70.1, 65.3, 41.5, 40.4; FTIR (NaCl, thin film): 3407, 2924, 2852, 1644, 1379, 1289, 1262, 1234, 1188, 1132, 1082, 1053, 971, 902, 861, 819, 744, 722, 622 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{16}N_2O_5S_4Cl$ $[M+Cl]^-$ 502.9636, found 502.9633.

The major side product aromatic diketopiperazine **22** was also isolated as a yellow solid (0.5 mg, 0.0016 mmol, 17% yield). $[\alpha]_D^{25}$ = –365° (*c* = 0.055, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.46 (dt, *J* = 8.3, 0.9 Hz, 1H), 7.74 (dt, *J* = 7.8, 1.0 Hz, 1H), 7.60 – 7.52 (m, 2H), 7.43 (ddd, *J* = 8.2, 7.3, 1.0 Hz, 1H), 6.61 (td, *J* = 2.5, 0.8 Hz, 1H), 6.22 (dd, *J* = 8.2, 2.3 Hz, 1H), 5.54 (br s, 1H), 5.04 (d, *J* = 7.9 Hz, 1H), 4.97 (dd, *J* = 8.2, 1.9 Hz, 1H), 4.69 (dd, *J* = 11.9, 6.4 Hz, 1H), 4.44 (d, *J* = 7.9 Hz, 1H), 3.20 (ddt, *J* = 14.0, 6.5, 1.2 Hz, 1H), 2.95 (ddt, *J* = 14.2, 12.0, 2.2 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ163.4, 158.1, 138.1, 138.0, 135.0, 129.2, 128.7, 128.5, 125.7, 122.9, 116.5, 115.6, 110.5, 109.4, 70.5, 64.3, 59.0, 34.7; FTIR (NaCl, thin film): 3391, 2926, 2854, 1713, 1695, 1652, 1634, 1588, 1575, 1446, 1390, 1362, 1336, 1312, 1284, 1252, 1212, 1192, 1182, 1135, 1079, 1046, 1006, 968, 844, 818, 789, 754, 667 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{13}N_2O_3$ $[M–OH]^+$ 305.0931, found 305.0921 (detected fragment has undergone loss of hydroxyl anion).

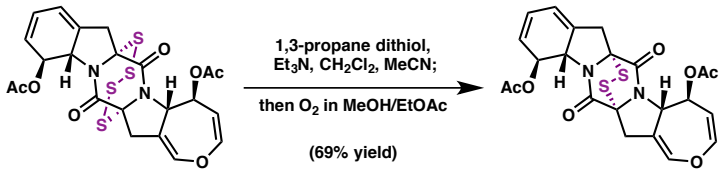
Preparation of diacetate S3



To a stirred solution of diol **21** (1.3 mg, 2.8 µmol, 1.0 equiv) and DMAP (8.5 mg, 69 µmol, 25 equiv) in CH_2Cl_2 (0.28 mL) at 0 °C was added acetyl chloride (3.0 µL, 42 µmol). After 10 min, the ice bath was removed and the reaction mixture was allowed to warm to room temperature. After an additional 30 min, the reaction mixture was quenched with saturated $NaHCO_3$ (0.5 mL) and extracted five times with a mixture of hexanes and EtOAc (1 : 1). Each organic fraction was passed individually through a plug of SiO_2, which was subsequently rinsed with excess hexanes/EtOAc (1 : 1). The combined filtrates were concentrated *in vacuo* to provide the crude

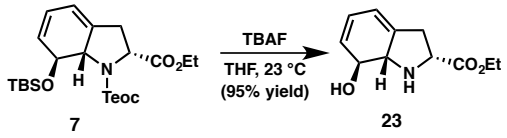
product, which was purified by preparative TLC (60% EtOAc in hexanes) to afford diacetate **S3**, as a yellow solid (1.0 mg, 1.8 µmol, 66% yield). $[\alpha]_D^{25}$ = –327° (*c* = 0.03, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 6.56 (t, *J* = 2.5 Hz, 1H), 6.26 (dd, *J* = 8.2, 2.3 Hz, 1H), 6.00 – 5.91 (m, 2H), 5.83 (d, *J* = 14.2 Hz, 1H), 5.68 – 5.59 (m, 1H), 5.37 (d, *J* = 14.4 Hz, 1H), 5.29 (d, *J* = 8.2 Hz, 1H), 5.22 (dt, *J* = 8.4, 2.1 Hz, 1H), 4.70 (dd, *J* = 8.2, 1.9 Hz, 1H), 3.31 – 3.21 (m, 2H), 3.04 (dd, *J* = 16.5, 6.4 Hz, 2H), 2.19 (s, 6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.4, 170.4, 166.6, 165.8, 139.6, 138.6, 131.9, 128.8, 124.9, 120.9, 108.1, 106.0, 79.4, 75.4, 74.2, 71.1, 64.2, 60.7, 41.8, 41.2, 21.5, 21.4; FTIR (NaCl, thin film): 2923, 2854, 1734, 1685, 1369, 1293, 1236, 1187, 1135, 1046, 753, 710 cm^{-1}; HRMS (LC-MM) calc'd for $C_{20}H_{17}N_2O_5S_4$ $[M–C_2H_3O_2]^+$ 493.0026, found 493.0015 (detected fragment has undergone loss of acetate anion).

Preparation of (–)-acetylapoaranotin (3)



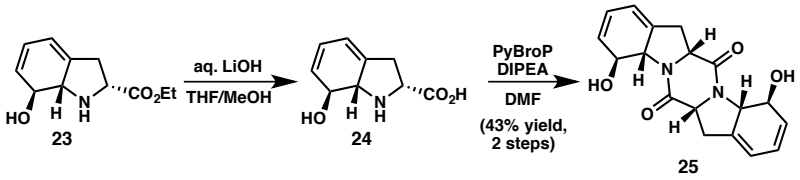
A solution of diacetate **S3** (1.0 mg, 1.8 µmol) in CH_2Cl_2 (0.2 mL) was diluted with MeCN (6 mL), then treated with a solution of Et_3N in MeCN (0.08 µL, 0.6 µmol in 20 µL of MeCN), followed by 1,3-propanedithiol (18 µL, 0.18 mmol, 100 equiv). The resulting mixture was allowed to stand for 20 min, and was then washed with hexanes (5 x 5 mL, the final hexanes wash was back-extracted once with MeCN (15 mL) to ensure material recovery), and concentrated *in vacuo*. The resulting residue was dissolved in CH_2Cl_2/PhMe and loaded onto a short plug of SiO_2. Residual propanedithiol and other nonpolar impurities were eluted with 20% EtOAc in hexanes before the presumed dithiol intermediate was eluted with 50 to 100% EtOAc in hexanes. The collected fractions were concentrated *in vacuo*. The resulting material was taken up in EtOAc (20 mL) and MeOH (20 mL). The resulting solution was sparged with O_2 for 2 hours and allowed to stir for another 12 hours. The solution was then concentrated *in vacuo*, and purified by preparative TLC (60% EtOAc in hexanes) to provide (–)-acetylapoaranotin (**3**) as a yellow solid (0.6 mg, 1.2 µmol, 69% yield). $[\alpha]_D^{25}$ = –281° (*c* = 0.015, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.60 (dd, *J* = 2.2, 2.2 Hz, 1H), 6.30 (dd, *J* = 8.2, 2.2 Hz, 1H), 6.04 (d, *J* = 12.4 Hz, 1H), 6.01 – 5.93 (m, 2H), 5.70 (ddd, *J* = 8.5, 2.0, 2.0 Hz, 1H), 5.55 (d, *J* = 8.2 Hz, 1H), 5.09 (dd, *J* = 8.8, 2.0 Hz, 1H), 4.99 (d, *J* = 12.6 Hz, 1H), 4.60 (dd, *J* = 8.3, 1.8 Hz, 1H), 4.01 (d, *J* = 17.9 Hz, 1H), 3.80 (d, *J* = 17.7 Hz, 1H), 2.99 (ddd, *J* = 18.3, 1.7, 1.7 Hz, 1H), 2.87 (d, *J* = 17.7 Hz, 1H), 2.14 (s, 3H), 2.03 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.5, 169.9, 163.1, 162.2, 141.1, 139.2, 132.2, 127.8, 124.5, 119.9, 113.4, 105.3, 78.2, 75.9, 73.9, 69.8, 64.5, 62.8, 36.1, 34.5, 21.3, 20.9; FTIR (NaCl, thin film): 2919, 2850, 1737, 1706, 1552, 1435, 1367, 1302, 1279, 1233, 1143, 1041, 962, 752, 720, 655 cm^{-1}; HRMS (ESI) calc'd for $C_{22}H_{20}N_2O_7S_2Na$ $[M+Na]^+$ 511.0610, found 511.0621.

Preparation of dienol 23



Cyclic diene **7** (28.6 mg, 0.061 mmol, 1.0 equiv) was dissolved in dry THF (1.1 mL) in a 1-dram vial. TBAF (1M in THF, 0.18 mL, 0.18 mmol, 3 equiv) was added and the resulting light brown solution was allowed to stir at room temperature for 2 hours and 20 minutes before being quenched with saturated Na_2SO_4 solution (2 mL). The mixture was further diluted with brine (1 mL) and extracted with EtOAc (12 x 5 mL). Each of the EtOAc extracts was filtered through a short silica gel plug. The combined organic layers were concentrated to give a light brown oil. Flash chromatography (60% to 100% EtOAc in hexanes) afforded dienol **23**, as a light brown oil (12.9 mg, 0.06 mmol, 95% calculated yield, accompanied by 5% aromatized side product). $[\alpha]_D^{25}$ = +190° (*c* = 0.60, CH_2Cl_2); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.84 (ddd, *J* = 9.7, 4.8, 2.8 Hz, 1H), 5.71 (dt, *J* = 4.9, 2.5 Hz, 1H), 5.65 (d, *J* = 9.8 Hz, 1H), 4.58 (d, *J* = 15.1 Hz, 1H), 4.21 (qd, *J* = 7.1, 2.5 Hz, 2H), 3.86 (t, *J* = 8.0 Hz, 1H), 3.82 (dd, *J* = 14.2, 2.8 Hz, 1H), 3.04 (br s, 2H), 2.90 (dd, *J* = 17.7, 8.3 Hz, 1H), 2.66 (dd, *J* = 17.6, 7.6 Hz, 1H), 1.29 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 173.2, 141.1, 130.3, 124.7, 115.9, 74.8, 66.4, 61.2, 59.3, 33.9, 14.2; FTIR (NaCl, thin film): 3337, 3043, 2980, 2928, 2853, 1738, 1553, 1446, 1377, 1329, 1200, 1082, 1061, 1033, 862, 750, 711 cm^{-1}; HRMS (MM) calc'd for $C_{11}H_{16}NO_3$ $[M+H]^+$ 210.1125, found 210.1125.

Preparation of *syn*-diol 25

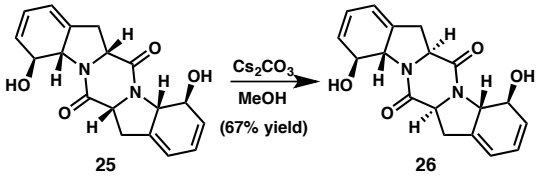


In a half dram vial, dienol **23** (1.2 mg, 0.006 mmol, 1.0 equiv) was dissolved in THF (50 μL) and MeOH (50 μL). A solution of LiOH (1.4 mg, 0.060 mmol, 10 equiv) in water (50 μL) was added into the vial and the reaction was allowed to stir at room temperature for 10 minutes. It was then quenched with 1M HCl (57 μL) and the solvent was removed under vacuum to provide a brown oil/solid crude material. It was subjected to the next reaction *directly*. Due to the high polarity of amino acid **24**, analytical pure sample could be obtained by preparative reverse phase HPLC (0% to 5% CH_3CN in H_2O over 10 minutes, t_R = 3.0-7.0 min). $[\alpha]_D^{25}$ = +254° (*c* = 0.33, MeOH); ^{1}H NMR (400 MHz, CD_3OD) δ 5.91 (ddd, *J* = 9.7, 4.9, 2.7 Hz, 1H), 5.84 (dt, *J* = 5.0, 2.6 Hz, 1H), 5.68 (dd, *J* = 9.7, 1.8 Hz, 1H), 4.81 (d, *J* = 14.9 Hz, 1H), 4.10 (d, *J* = 15.5 Hz, 1H), 4.03 (dd, *J* = 9.1, 7.4 Hz, 1H), 3.05 (dd, *J* = 17.9, 9.0 Hz, 1H), 2.81 (dd, *J* = 17.7, 7.3 Hz, 1H); ^{13}C NMR (101 MHz, CD_3OD) δ 174.7, 138.1, 131.3, 125.7, 118.7, 72.3, 67.8, 62.9, 33.8; FTIR (NaCl, thin film): 3380, 3044, 2916, 2849, 1624, 1417,

1380, 1314, 1253, 1145, 1068, 987, 875, 833, 794, 762, 712, 624 cm^{-1}; HRMS (MM) calc'd for $C_9H_{12}NO_3$ $[M+H]^+$ 182.0812, found 182.0815.

The crude material was first dissolved in small amount of MeOH (ca. 0.1 mL) and co-evaporated with benzene to further remove water. It was then dissolved in DMF (0.3 mL). Under N_2, DIPEA (6 µL, 0.034 mmol, 6 equiv), and PyBroP (10.7 mg, 0.023 mmol, 4 equiv) were added in sequence. The resulting light brown solution was allowed to stir at room temperature for 22 hours. It was then quenched with saturated $NaHCO_3$ (1 mL). The mixture was separated and the aqueous layer was then extracted with CH_2Cl_2 (5 x 1 mL). The combined organic layers were washed with brine (5 mL), dried over Na_2SO_4, filtered, and concentrated to give a light brown oil. Preparative TLC (80% EtOAc in hexanes) afforded *syn*-diol **25**, as a white solid (0.4 mg, 0.0012 mmol, 43% yield over 2 steps). $[\alpha]_D^{25}$ = +230° (*c* = 0.06, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.41 (d, *J* = 1.3 Hz, 1H), 5.93 (ddd, *J* = 9.5, 5.0, 2.8 Hz, 1H), 5.89 – 5.82 (m, 1H), 5.75 (ddt, *J* = 9.6, 2.0, 1.0 Hz, 1H), 4.75 – 4.65 (m, 1H), 4.48 (dd, *J* = 13.2, 3.0 Hz, 1H), 4.41 (dd, *J* = 10.2, 6.6 Hz, 1H), 3.34 – 3.18 (m, 1H), 3.16 – 2.93 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 168.4, 133.4, 129.5, 123.6, 118.7, 71.8, 68.9, 60.5, 29.3; FTIR (NaCl, thin film): 3281, 2922, 2853, 1651, 1423, 1381, 1351, 1336, 1295, 1273, 1255, 1230, 1192, 1147, 1083, 1061, 721, 671 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{19}N_2O_4$ $[M+H]^+$ 327.1339, found 327.1342.

Preparation of *anti*-diol 26



A 1-dram vial was charged with *syn*-diol **25** (1.2 mg, 0.0037 mmol, 1.0 equiv) and Cs_2CO_3 (48 mg, 0.147 mmol, 40 equiv). Dry MeOH (0.75 mL) was fully degassed by bubbling N_2 through and was added to the vial under N_2. The resulting mixture gradually turned into a clear yellow solution and was stirred for 30 minutes. It was then quenched with saturated $NaHCO_3$ (3 mL) and the mixture was extracted with EtOAc (5 x 3 mL). The combined organic layers were washed with brine (15 mL), dried over Na_2SO_4, filtered, and concentrated to give a white solid. Flash chromatography (20% to 100% EtOAc in hexanes) afforded *anti*-diol **26**, as a white solid (0.8 mg, 0.0024 mmol, 67% yield). $[\alpha]_D^{25}$ = –159° (*c* = 0.075, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.00 (s, 1H), 5.96 – 5.86 (m, 2H), 5.76 (dt, *J* = 9.5, 1.4 Hz, 1H), 4.78 – 4.63 (m, 3H), 2.99 (dd, *J* = 15.5, 7.2 Hz, 1H), 2.88 (t, *J* = 13.5 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.2, 132.7, 130.0, 123.0, 119.0, 73.6, 68.1, 62.5, 32.2; FTIR (NaCl, thin film): 3305, 3039, 2924, 2853, 2713, 1626, 1553, 1447, 1381, 1354, 1330, 1290, 1265, 1237, 1201, 1139, 1087, 1057, 767, 710 cm^{-1}; HRMS (MM) calc'd for $C_{18}H_{19}N_2O_4$ $[M+H]^+$ 327.1339, found 327.1336.

Table S1. Comparison of ^{1}H NMR data for natural vs. synthetic (–)-acetylapoaranotin (**3**)

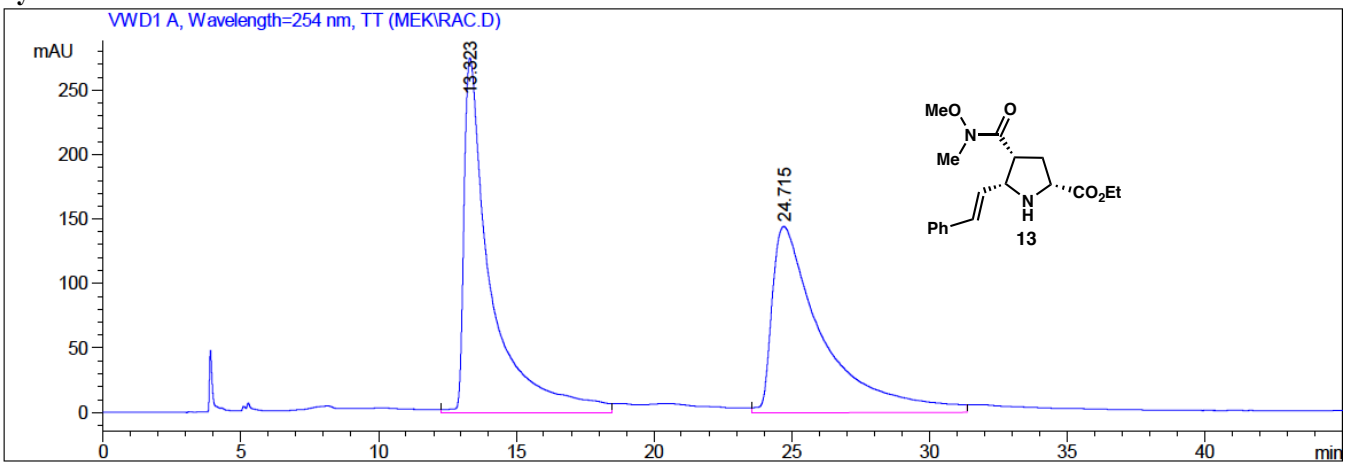
Yang et al. Report,[5] Natural (–)-acetylapoaranotin ^{1}H NMR, 500 MHz, $CDCl_3$	This Work, Synthetic (–)-acetylapoaranotin ^{1}H NMR, 400 MHz, $CDCl_3$
δ 6.61 (br ddd, *J* = 2.5, 2.0, 2.0 Hz, 1H)	δ 6.60 (dd, *J* = 2.2, 2.2 Hz, 1H)
6.31 (dd, *J* = 8.5, 2.0 Hz, 1H)	6.30 (dd, *J* = 8.2, 2.2 Hz, 1H)
6.05 (br dm, *J* = 13.2 Hz, 1H)	6.04 (d, *J* = 12.4 Hz, 1H)
5.99 (m, 1H)	6.01-5.93 (m, 2H)
5.96 (m, 1H)	
5.70 (ddd, *J* =8.5, 2.0, 2.0 Hz, 1H)	5.70 (ddd, *J* = 8.5, 2.0, 2.0 Hz, 1H)
5.56 (br dm, *J* = 13.2 Hz, 1H)	5.55 (d, *J* = 8.2 Hz, 1H)
5.10 (br dddd, *J* = 8.5, 2.0, 2.0, 1.5, 1H)	5.09 (dd, *J* = 8.8, 2.0 Hz, 1H)
5.00 (br dm, *J* = 13.2 Hz, 1H)	4.99 (d, *J* = 12.6 Hz, 1H)
4.61 (dd, *J* = 8.5, 2.0 Hz, 1H)	4.60 (dd, *J* = 8.3, 1.8 Hz, 1H)
4.02 (br ddd, *J* = 18.0, 2.5, 1.5 Hz, 1H)	4.01 (d, *J* = 17.9 Hz, 1H)
3.81 (dm, *J* = 18.5 Hz, 1H)	3.80 (d, *J* = 17.7 Hz, 1H)
2.99 (ddd, *J* = 18.0, 2.0, 2.0 Hz, 1H)	2.99 (ddd, *J* = 18.3, 1.7, 1.7 Hz, 1H)
2.88(br dd, *J* = 18.5, 1.5, 1H)	2.87 (d, *J* = 17.7 Hz, 1H)
2.15 (s, 3H)	2.14 (s, 3H)
2.03 (s, 3H)	2.03 (s, 3H)

Table S2. Comparison of ^{13}C NMR data for natural vs. synthetic (–)-acetylapoaranotin (**3**)

Yang et al. Report,[5] Natural (–)-acetylapoaranotin ^{13}C NMR, 126 MHz, $CDCl_3$	This Work, Synthetic (–)-acetylapoaranotin ^{13}C NMR, 101 MHz, $CDCl_3$	Chemical Shift Difference, Δδ
δ 170.5	δ 170.5	0.0
170.0	169.9	0.1
163.1	163.1	0.0
162.2	162.2	0.0
141.2	141.1	0.1
139.2	139.2	0.0
132.2	132.2	0.0
127.8	127.8	0.0
124.5	124.5	0.0
119.9	119.9	0.0
113.4	113.4	0.0
105.3	105.3	0.0
78.2	78.2	0.0
75.9	75.9	0.0
73.9	73.9	0.0
69.8	69.8	0.0
64.5	64.5	0.0
62.9	62.8	0.1
36.1	36.1	0.0
34.5	34.5	0.0
21.3	21.3	0.0
21.0	20.9	0.1

Chiral HPLC Traces:

Pyrrolidine 13: racemic



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
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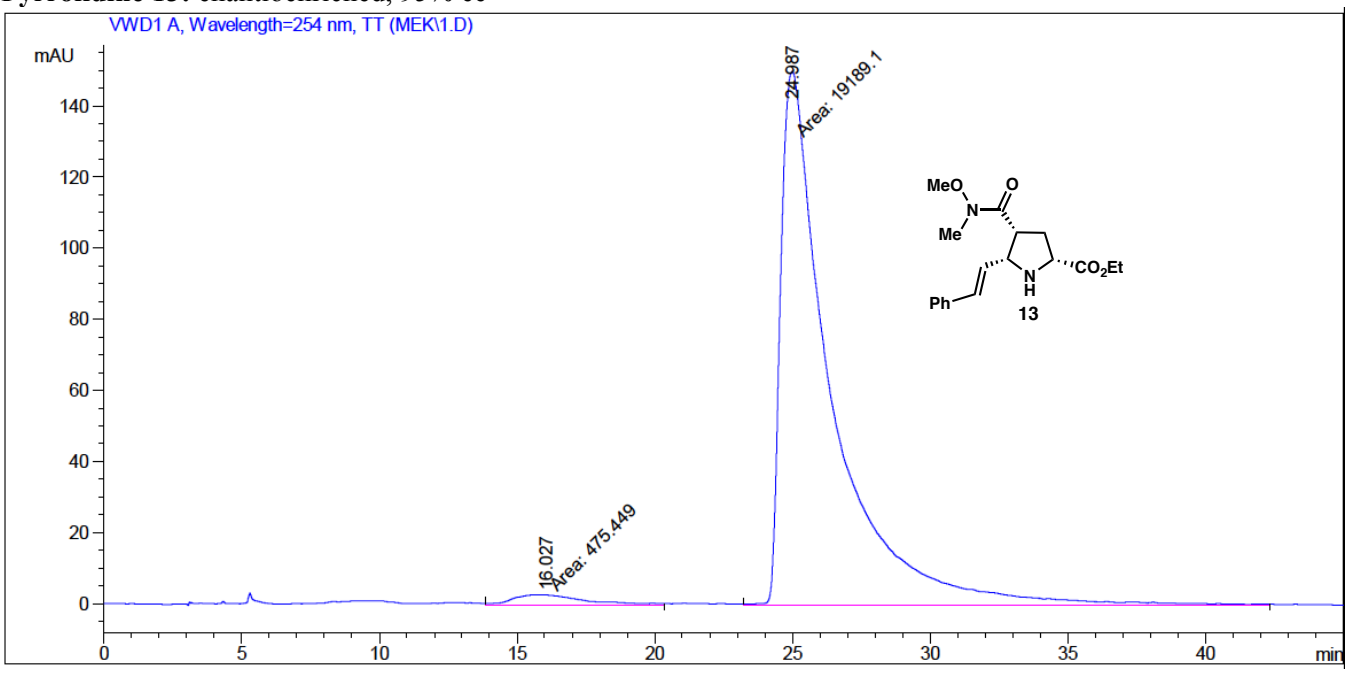
2	24.715	VV	1.7546	1.84898e4	144.25124	49.8321

Pyrrolidine 13: enantioenriched, 95% ee



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	16.027	MM	2.9130	475.44940	2.72031	2.4178
2	24.987	MM	2.1332	1.91891e4	149.92198	97.5822

References

[1] Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem*. **1978**, *43*, 2923.

[2] Procedures are modified based on the original report by the Tokuyama group. See: Fujiwara, H.; Kurogi, T.; Okaya, S.; Okano, K.; Tokuyama, H. *Angew. Chem. Int. Ed.* **2012**, *51*, 13062

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Enantioselective Synthesis of (–)-Acetylapoaranotin

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Supporting Information 2 (NMR Spectral Data):

WHX-7-197-F-RE-INDY-CDCL3

Sample Name:
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Data Collected on:
indy.caltech.edu-inova500
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Sample directory:
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FidFile: WHX-7-197-F-RE-INDY-CDCL3

Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: Jun 4 2015

Sample #11, Operator: hxwang

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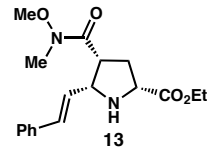

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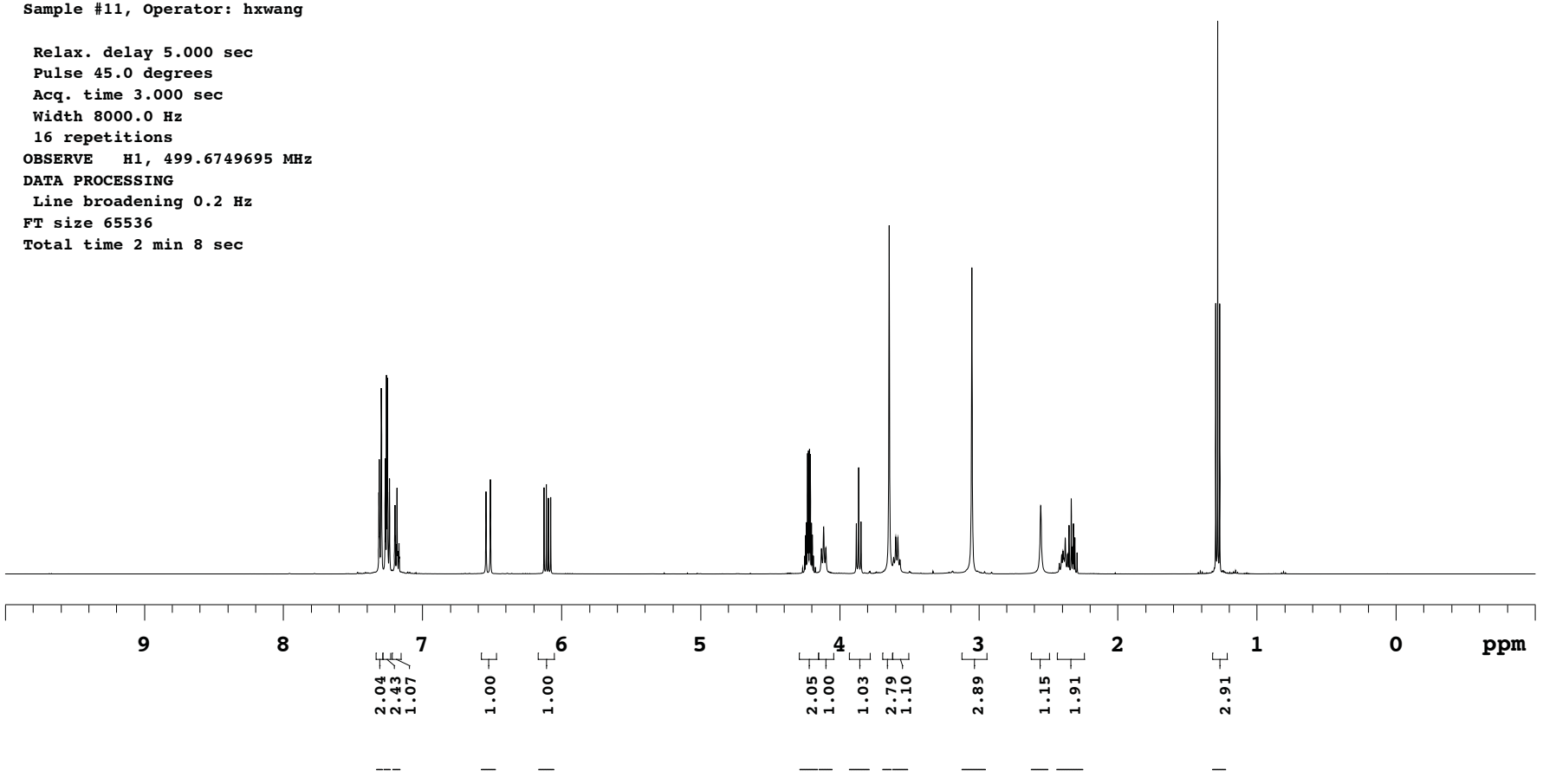

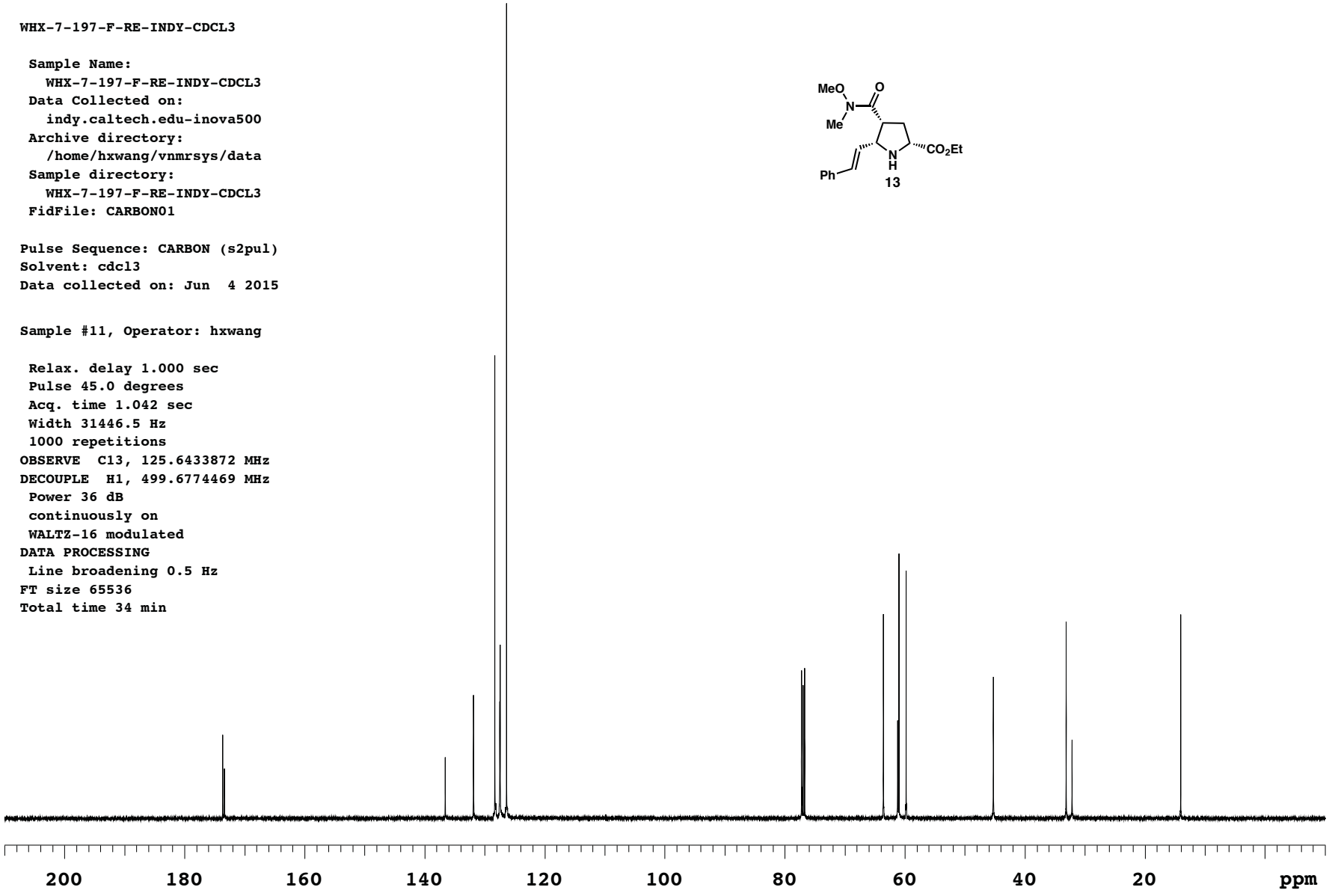
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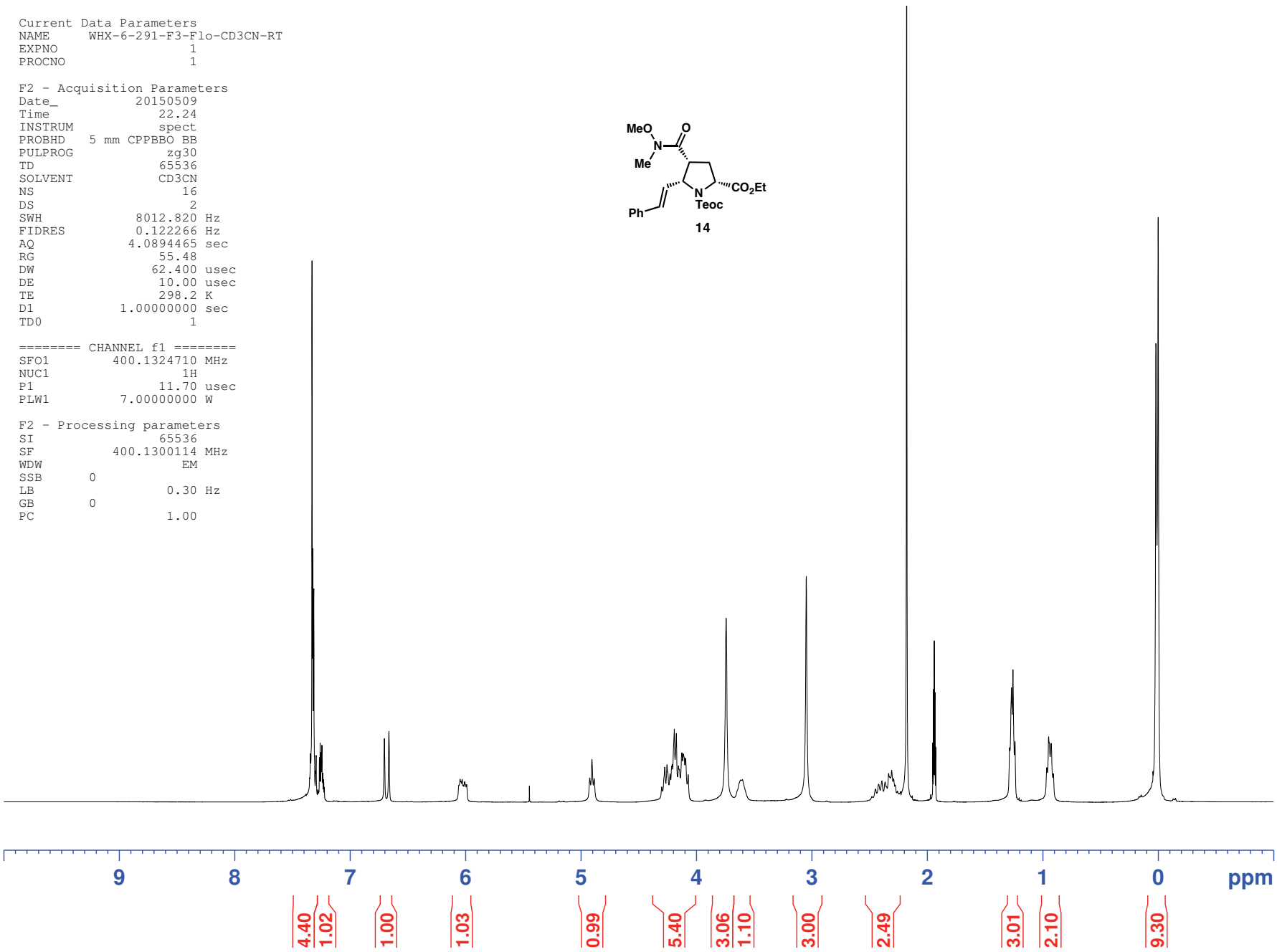
ppm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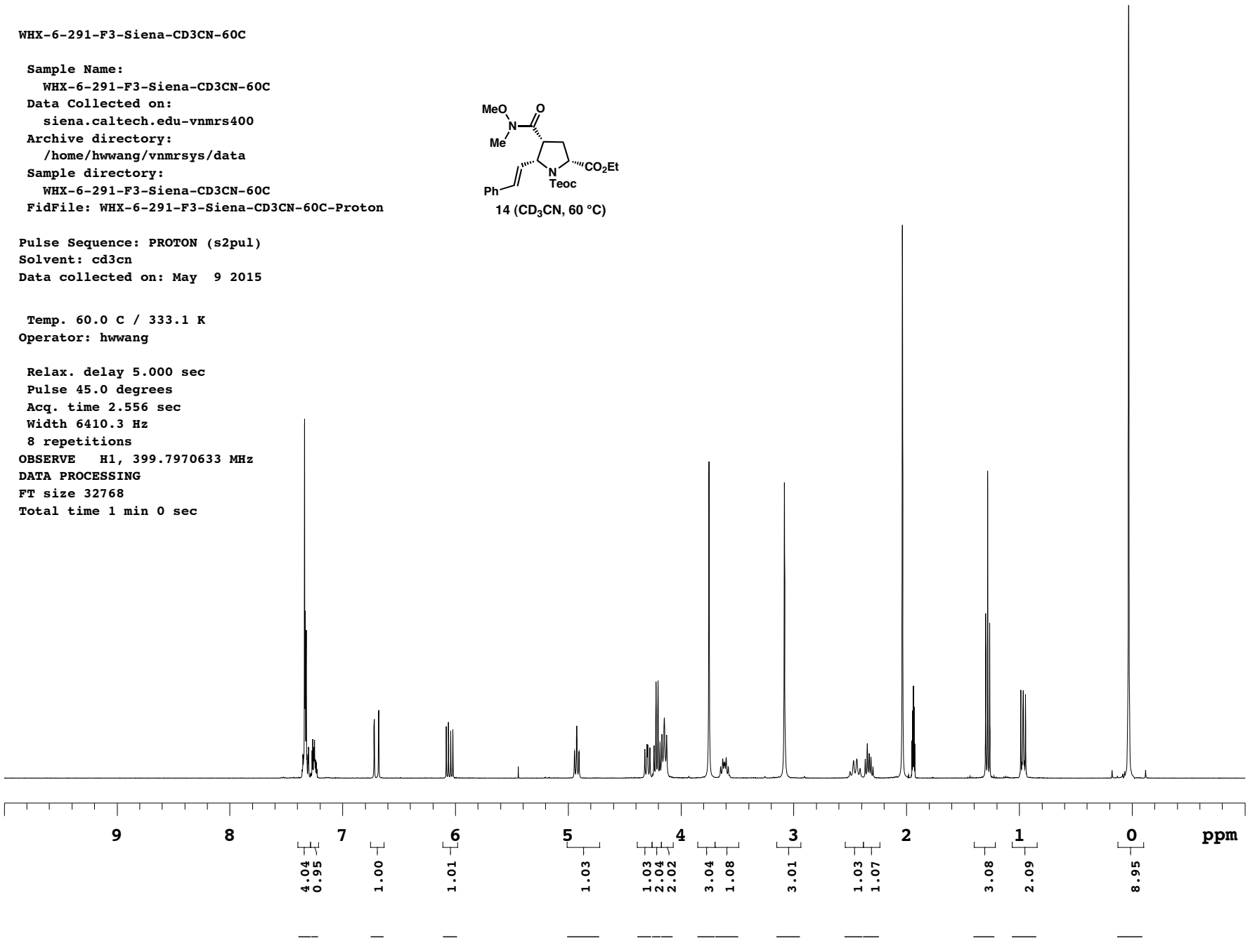
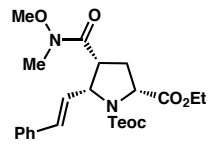
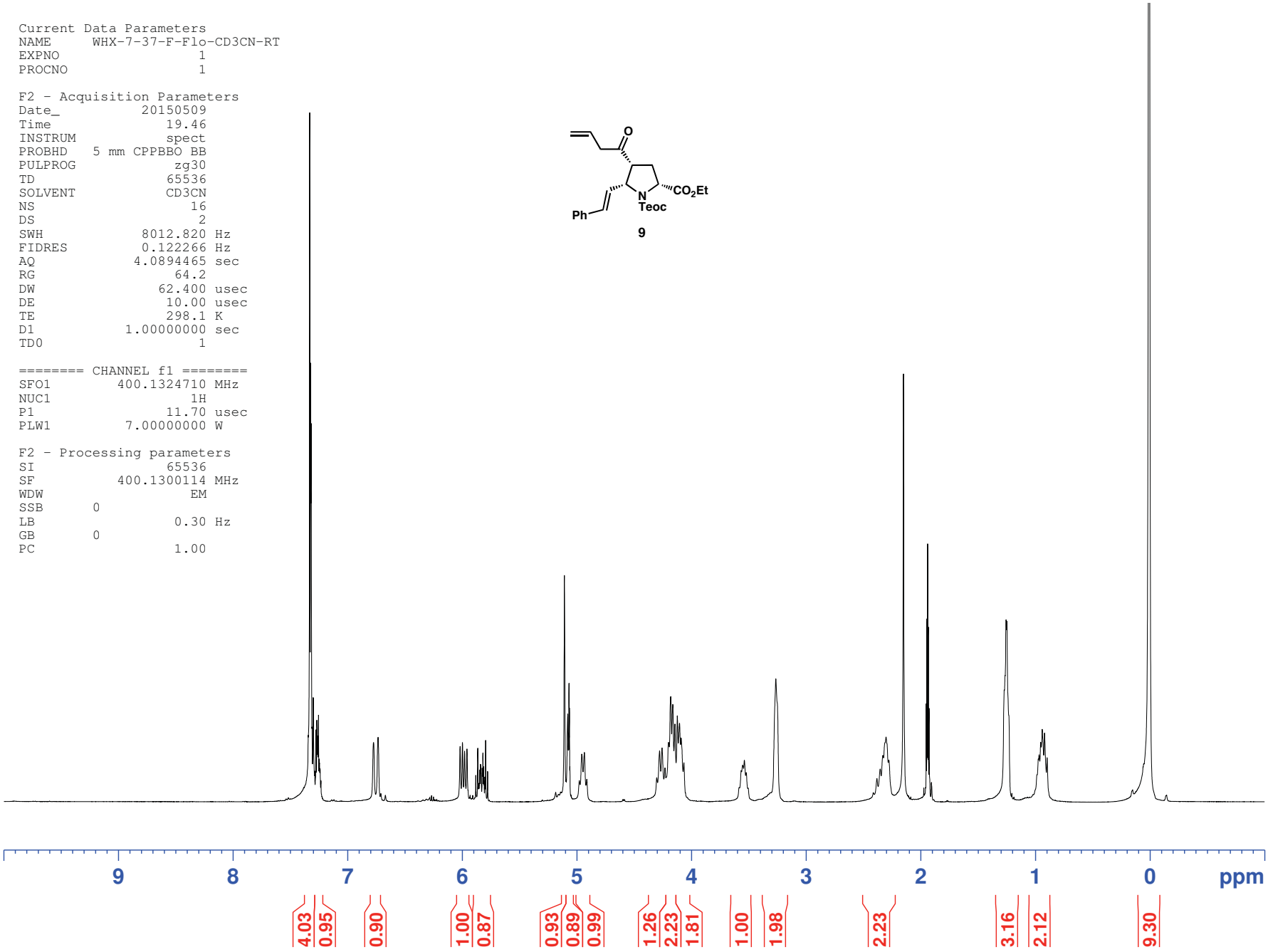
14
9
8
7
6
5
4
3
2
1
0
ppm
4.40
1.02
1.00
1.03
0.99
5.40
3.06
1.10
3.00
2.49
3.01
2.10
9.30

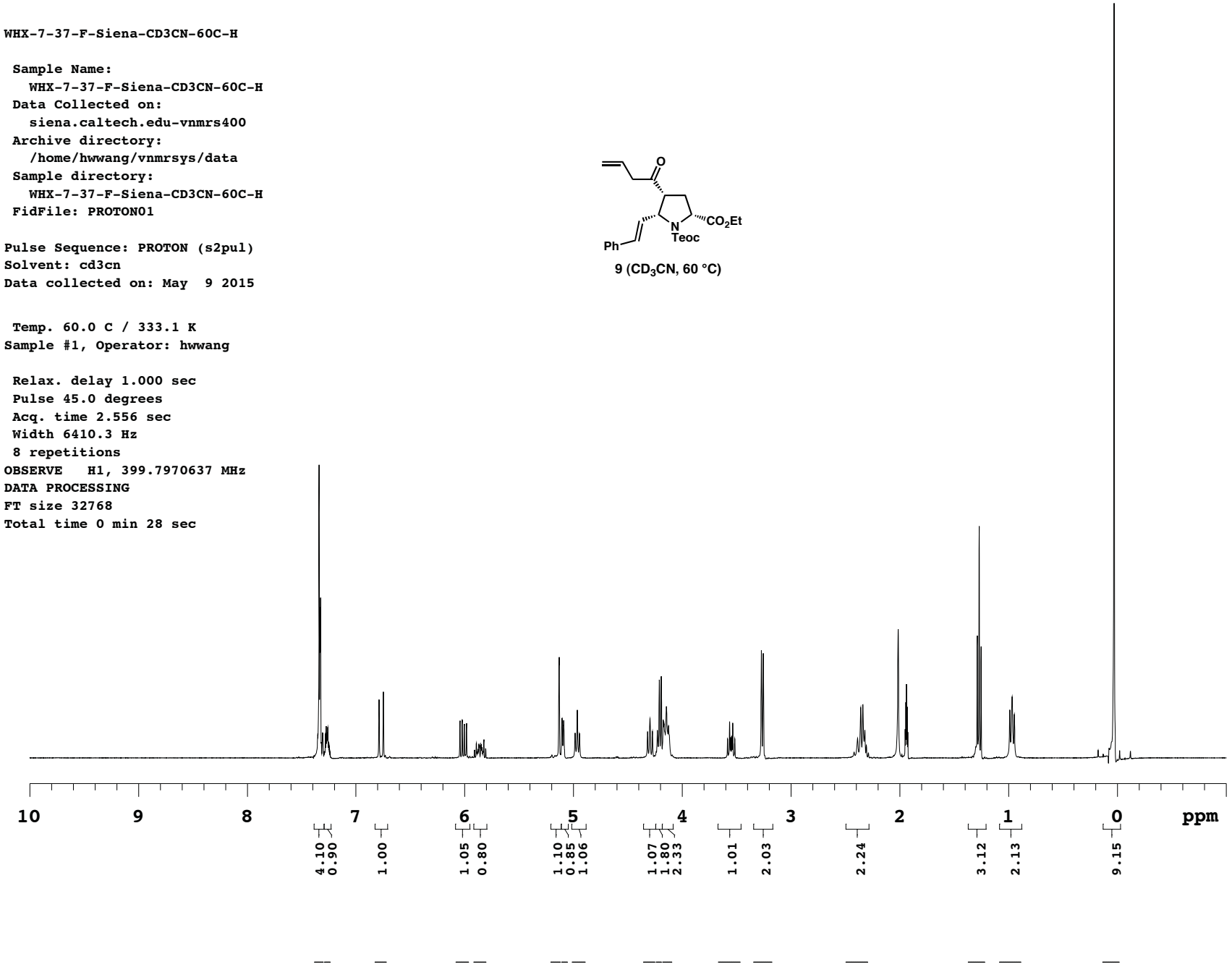

WHX-6-291-F3-Siena-CD3CN-60C
Sample Name:
WHX-6-291-F3-Siena-CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-6-291-F3-Siena-CD3CN-60C
FidFile: WHX-6-291-F3-Siena-CD3CN-60C-Proton
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 9 2015
Temp. 60.0 C / 333.1 K
Operator: hwwang
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
FT size 32768
Total time 1 min 0 sec
MeO
N
O
Me
N
CO2Et
Teoc
Ph
14 (CD3CN, 60 °C)
9
8
7
6
5
4
3
2
1
0
ppm
4.04
0.95
1.00
1.01
1.03
1.03
2.04
2.02
3.04
1.08
3.01
1.03
1.07
3.08
2.09
8.95

```
Current Data Parameters
NAME     WHX-6-291-F3-Flo-CD3CN-RT
EXPNO                 30
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150510
Time                0.25
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG           zgpg30
TD                 65384
SOLVENT            CD3CN
NS                  3000
DS                     4
SWH            24038.461 Hz
FIDRES          0.367651 Hz
AQ             1.3599873 sec
RG                 72.02
DW                20.800 usec
DE                 82.37 usec
TE                 298.2 K
D1            1.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         100.6228293 MHz
NUC1                13C
P1                 10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2              90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6126713 MHz
WDW                   EM
SSB      0
LB                 1.00 Hz
GB       0
PC                 1.40
```

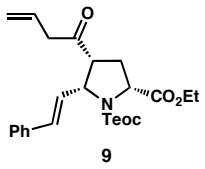


14


Current Data Parameters
NAME WHX-7-37-F-Flo-CD3CN-RT
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20150509
Time 19.46
INSTRUM spect
PROBHD 5 mm CPPBBO BB
PULPROG zg30
TD 65536
SOLVENT CD3CN
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.122266 Hz
AQ 4.0894465 sec
RG 64.2
DW 62.400 usec
DE 10.00 usec
TE 298.1 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
SFO1 400.1324710 MHz
NUC1 1H
P1 11.70 usec
PLW1 7.00000000 W
F2 - Processing parameters
SI 65536
SF 400.1300114 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
O
CO2Et
N
Teoc
Ph
9
9
8
7
6
5
4
3
2
1
0
ppm
4.03
0.95
0.90
1.00
0.87
0.93
0.89
0.99
1.26
2.23
1.81
1.00
1.98
2.23
3.16
2.12
9.30


WHX-7-37-F-Siena-CD3CN-60C-H
Sample Name:
WHX-7-37-F-Siena-CD3CN-60C-H
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-37-F-Siena-CD3CN-60C-H
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 9 2015
Temp. 60.0 C / 333.1 K
Sample #1, Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970637 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec
O
CO2Et
N
Teoc
Ph
9 (CD3CN, 60 °C)
10
9
8
7
6
5
4
3
2
1
0
ppm
4.10
0.90
1.00
1.05
0.80
1.10
0.85
1.06
1.07
1.80
2.33
1.01
2.03
2.24
3.12
2.13
9.15

```
Current Data Parameters
NAME     WHX-7-37-F-Flo-CD3CN-RT
EXPNO                 30
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150509
Time                21.49
INSTRUM             spect
PROBHD   5 mm CPPBBO BB
PULPROG           zgpg30
TD                 65384
SOLVENT            CD3CN
NS                  3000
DS                     4
SWH            24038.461 Hz
FIDRES          0.367651 Hz
AQ             1.3599873 sec
RG                 78.69
DW                20.800 usec
DE                 82.37 usec
TE                 298.1 K
D1            1.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         100.6228293 MHz
NUC1                13C
P1                 10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2              90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6126706 MHz
WDW                  EM
SSB      0
LB                  1.00 Hz
GB       0
PC                  1.40
```



9

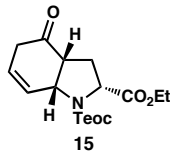
WHX-7-177-F-Siena-CD3CN

Sample Name:
WHX-7-177-F-Siena-CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-177-F-Siena-CD3CN
FidFile: PROTON01

Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 11 2015

Temp. 25.0 C / 298.1 K
Sample #2, Operator: hwwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970641 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec



15

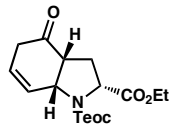
WHX-7-177-F-Siena-CD3CN-65C

Sample Name:
WHX-7-177-F-Siena-CD3CN-65C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-177-F-Siena-CD3CN-65C
FidFile: WHX-7-177-F-Siena-CD3CN-65C-Proton

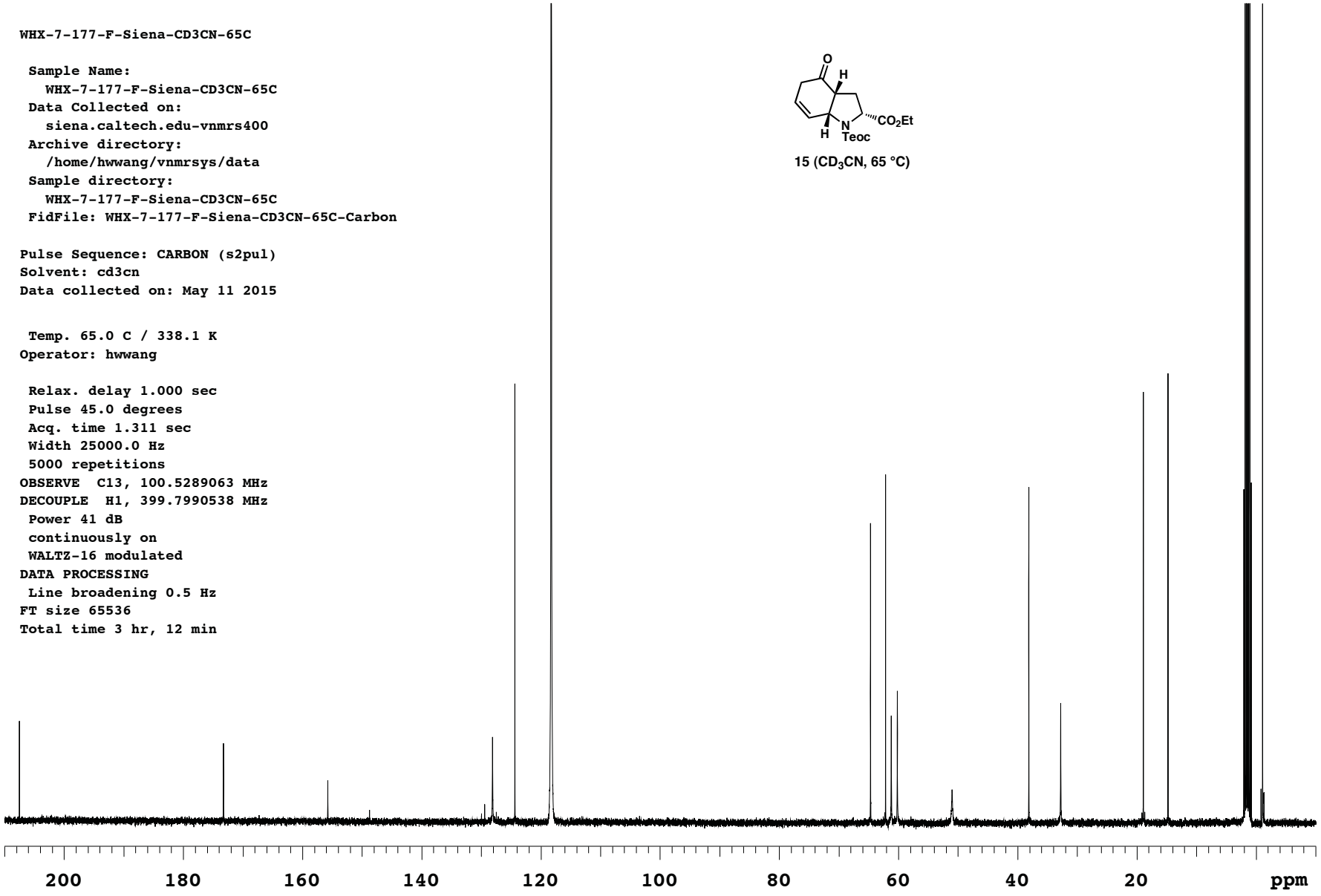
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 11 2015

Temp. 65.0 C / 338.1 K
Operator: hwwang

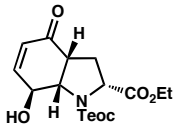
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec



15 (CD_3CN, 65 °C)

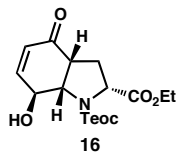

WHX-7-177-F-Siena-CD3CN-65C
Sample Name:
WHX-7-177-F-Siena-CD3CN-65C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-177-F-Siena-CD3CN-65C
FidFile: WHX-7-177-F-Siena-CD3CN-65C-Carbon
Pulse Sequence: CARBON (s2pul)
Solvent: cd3cn
Data collected on: May 11 2015
Temp. 65.0 C / 338.1 K
Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
5000 repetitions
OBSERVE C13, 100.5289063 MHz
DECOUPLE H1, 399.7990538 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 3 hr, 12 min
O
H
CO2Et
N
H
Teoc
15 (CD3CN, 65 °C)
200
180
160
140
120
100
80
60
40
20
ppm

```
Current Data Parameters
NAME      WHX-7-70-HPLC-F1-Flo-CDCL3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150430
Time              21.11
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8012.820 Hz
FIDRES          0.122266 Hz
AQ             4.0894465 sec
RG                 30.29
DW                62.400 usec
DE                10.00 usec
TE                298.1 K
D1           2.00000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                  1H
P1                 11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                 65536
SF           400.1300095 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

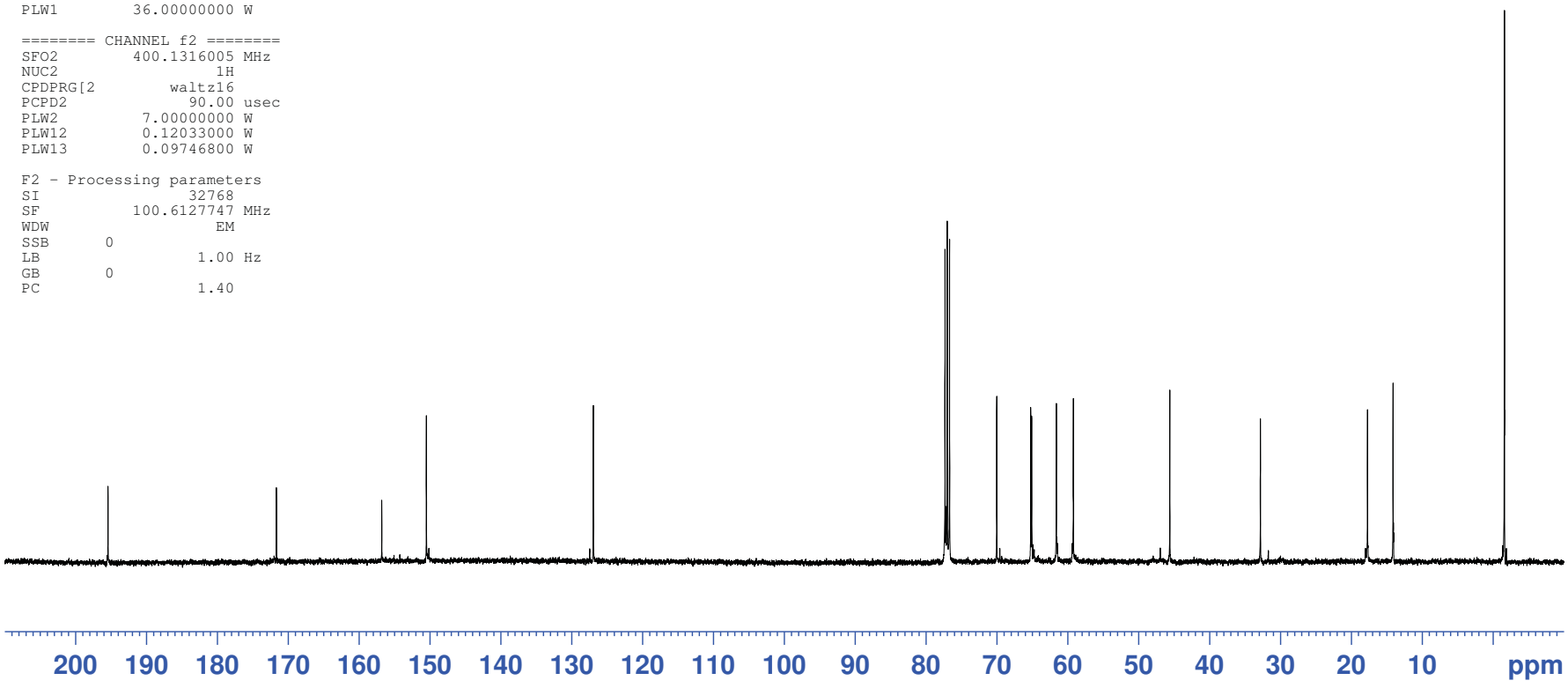


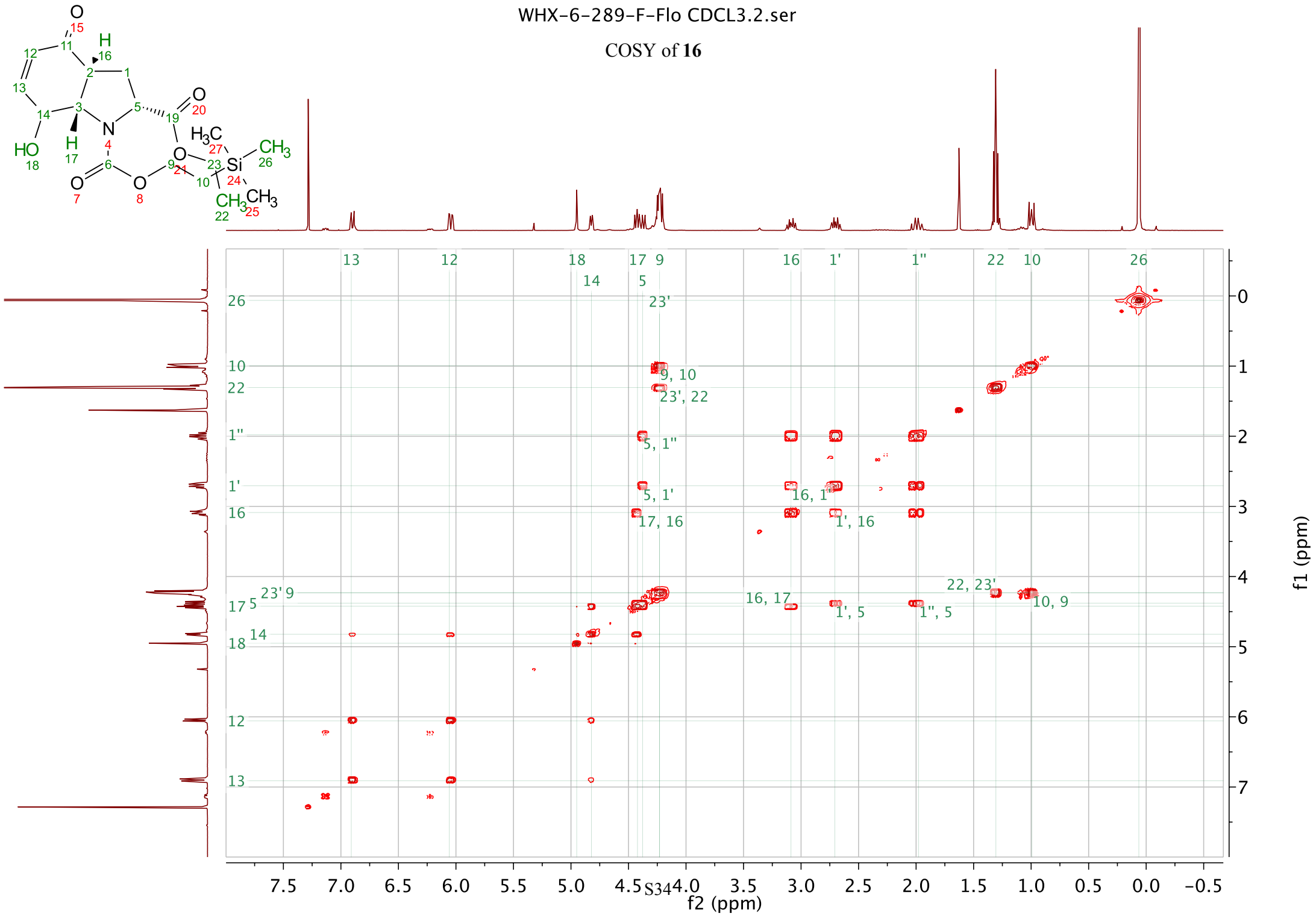
16

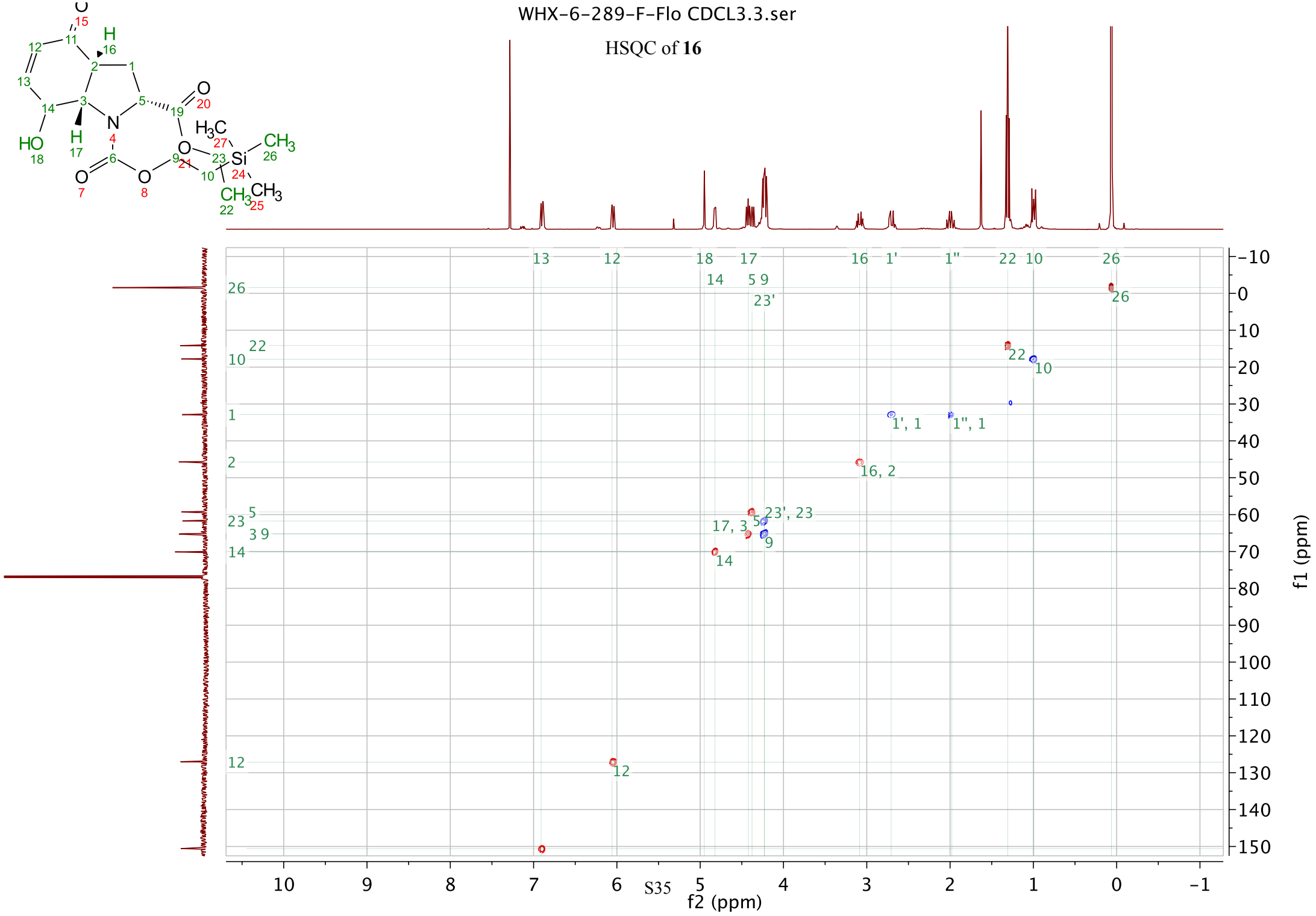
```
Current Data Parameters
NAME      WHX-7-70-HPLC-F1-Flo-CDCL3
EXPNO                  2
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150430
Time               21.17
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   128
DS                     2
SWH            24038.461 Hz
FIDRES          0.366798 Hz
AQ             1.3631488 sec
RG                 72.02
DW                20.800 usec
DE                82.37 usec
TE                298.1 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                   18

======== CHANNEL f1 ========
SFO1         100.6228298 MHz
NUC1                13C
P1                10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                 1H
CPDPRG[2         waltz16
PCPD2               90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF            100.6127747 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

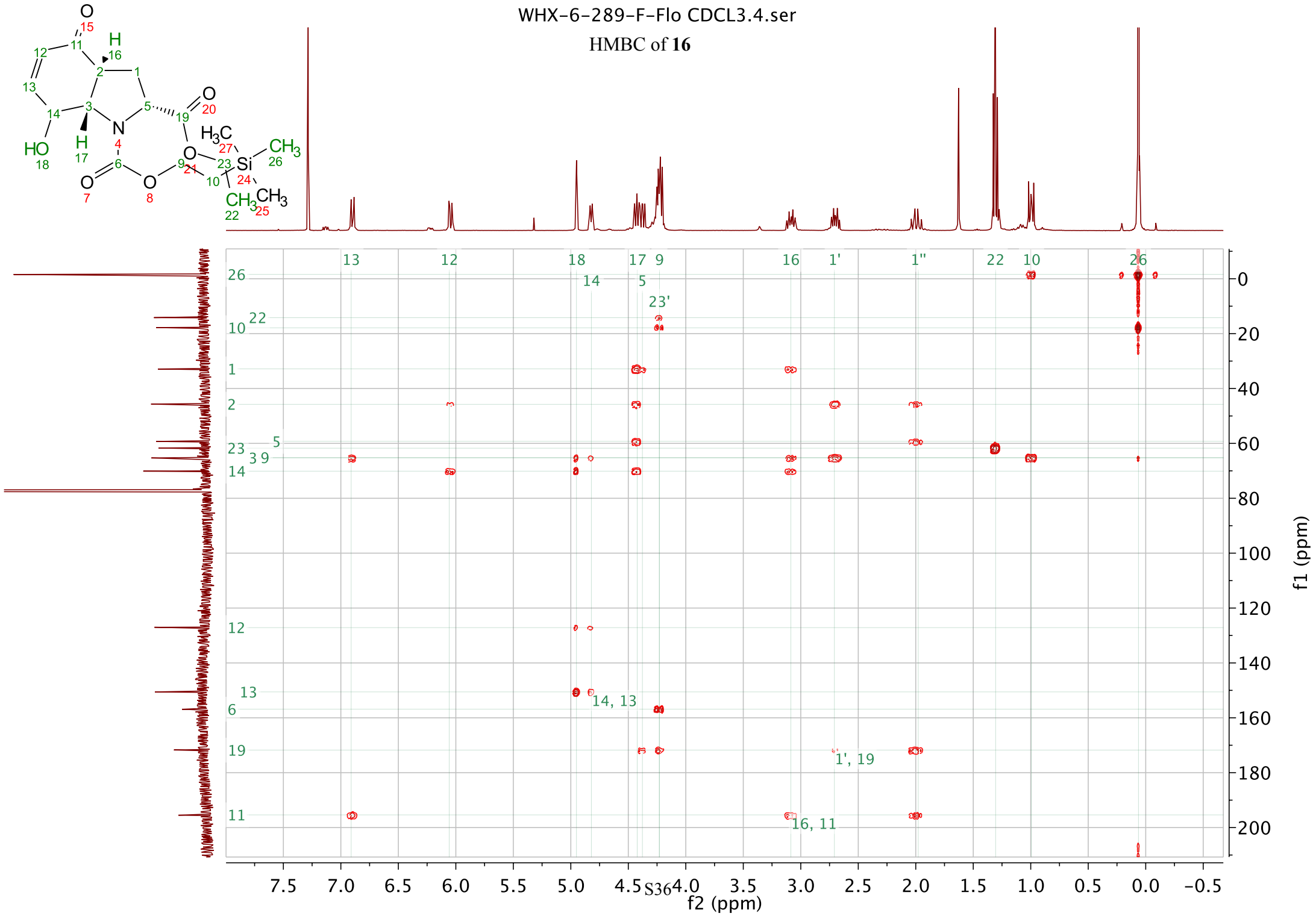


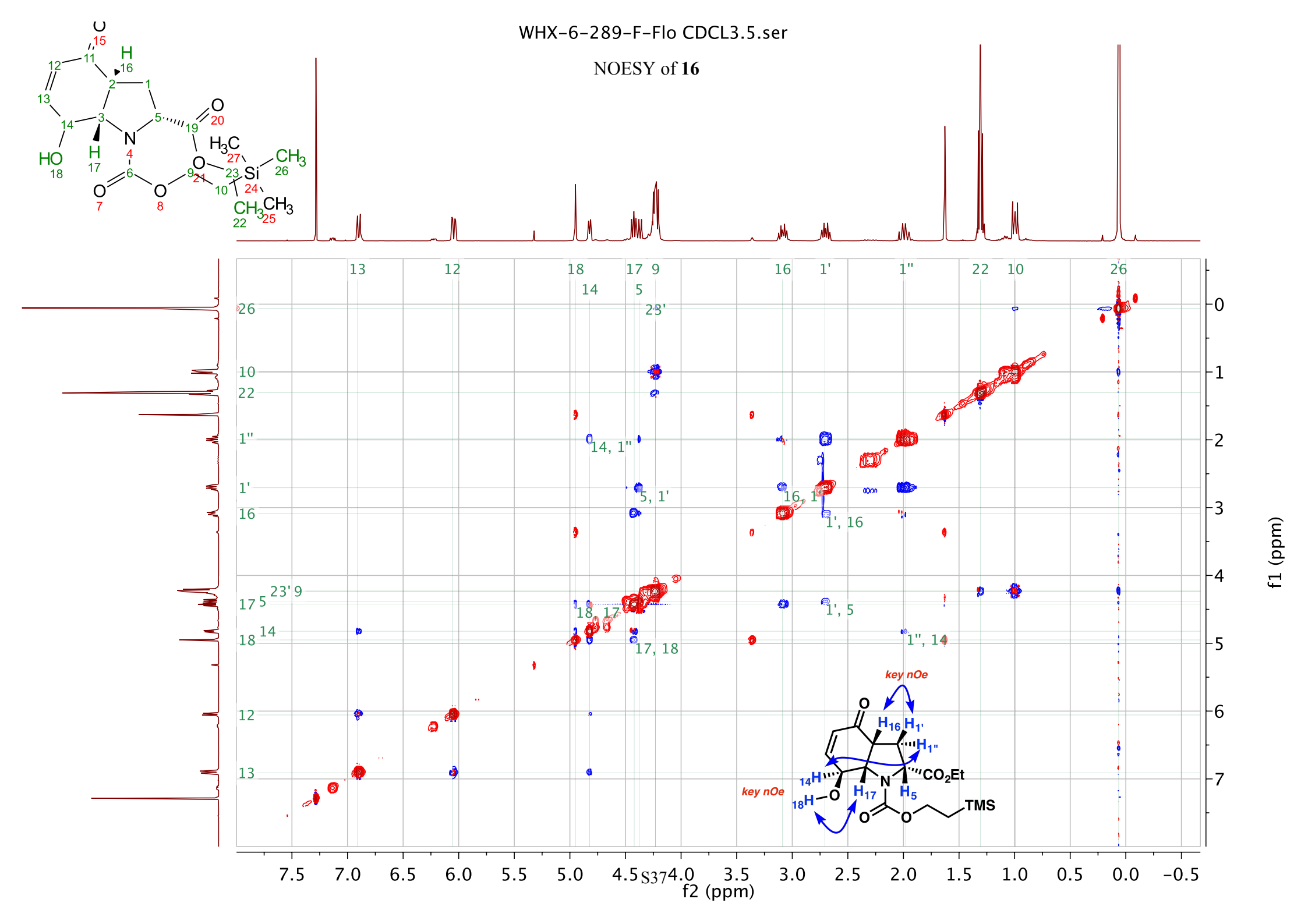
16

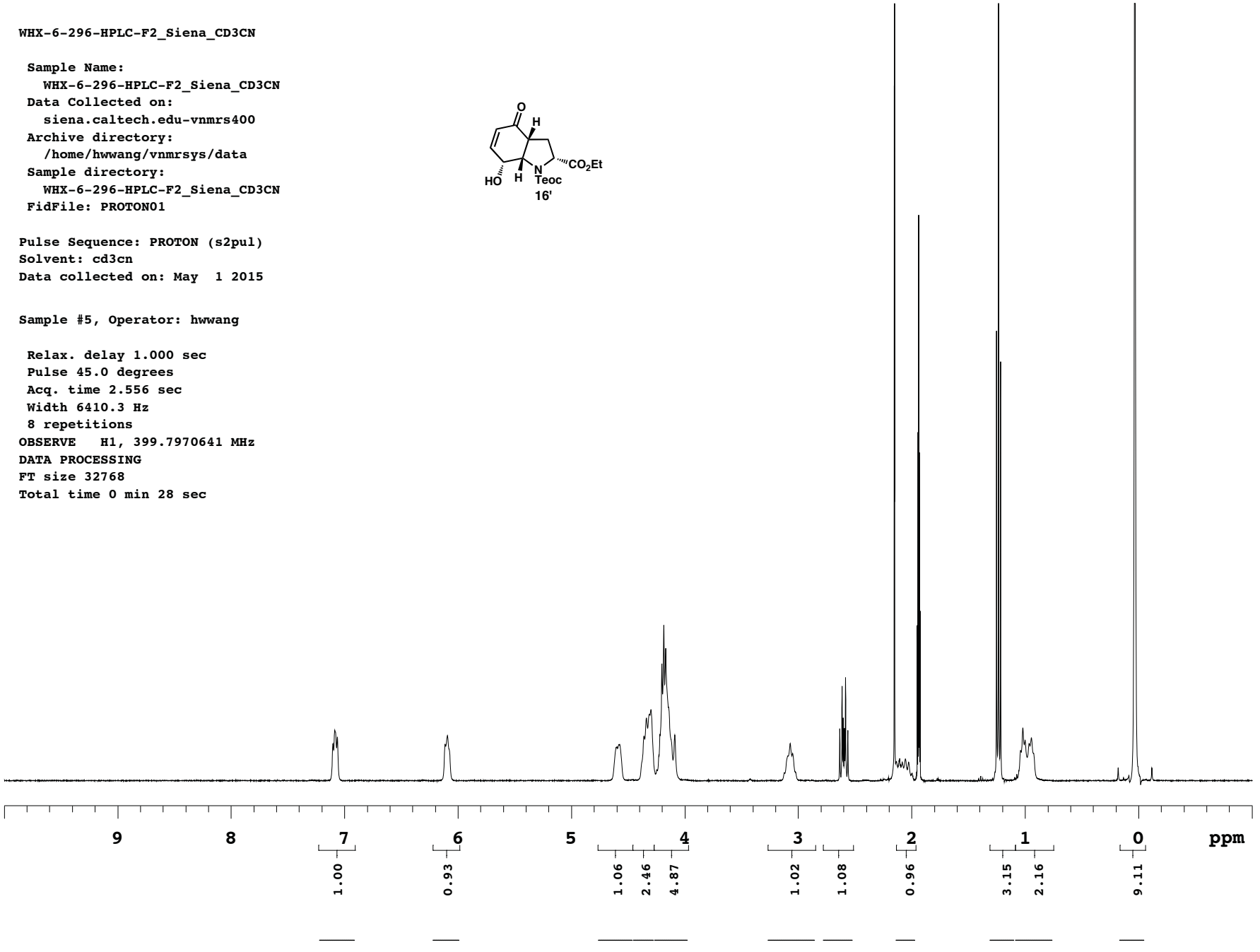


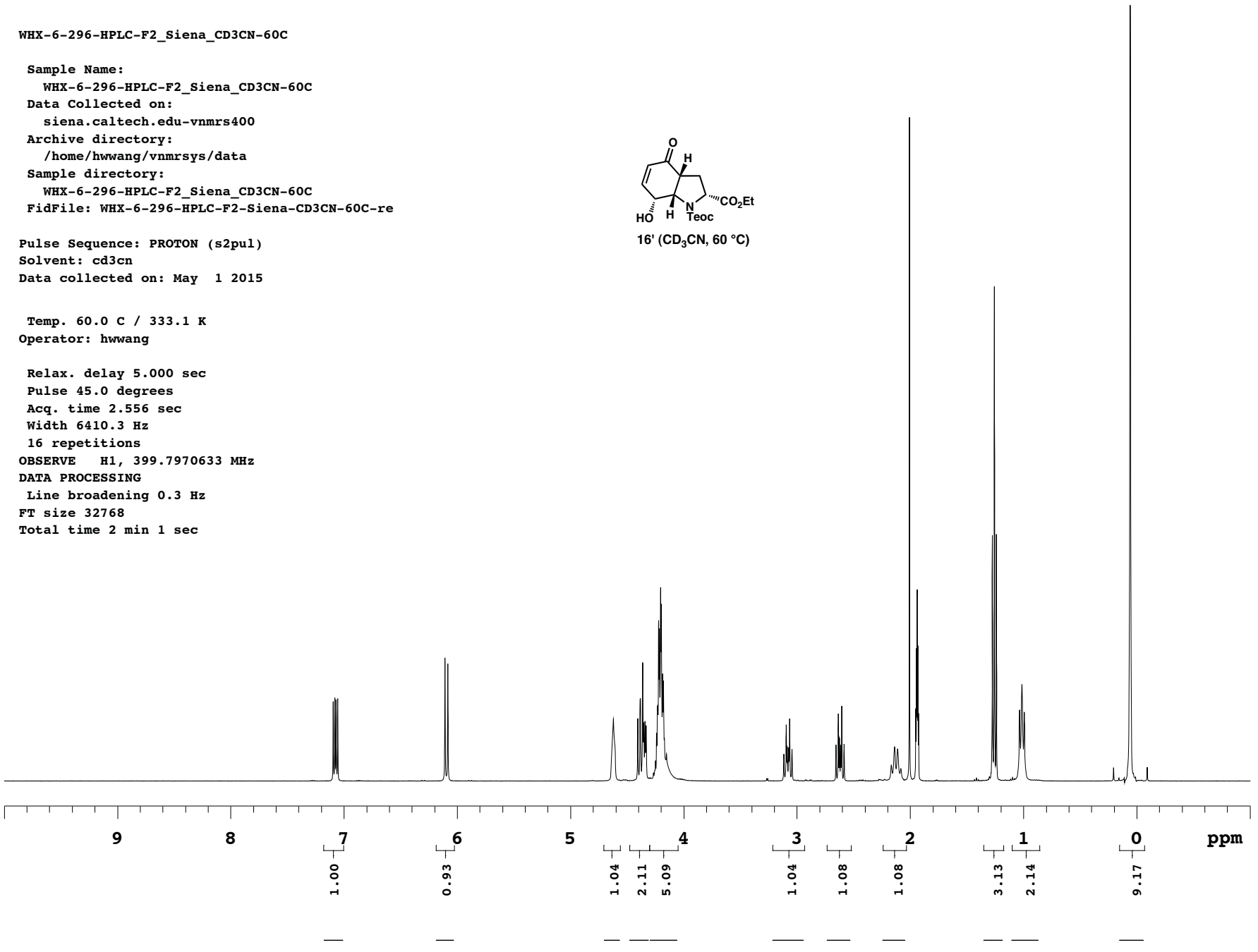

WHX-6-289-F-Flo CDCL3.2.ser
COSY of 16
f2 (ppm)
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
1
2
3
4
5
6
7
9, 10
23', 22
5, 1"
5, 1'
17, 16
16, 1'
1', 16
16, 17
1', 5
1", 5
22, 23'
10, 9

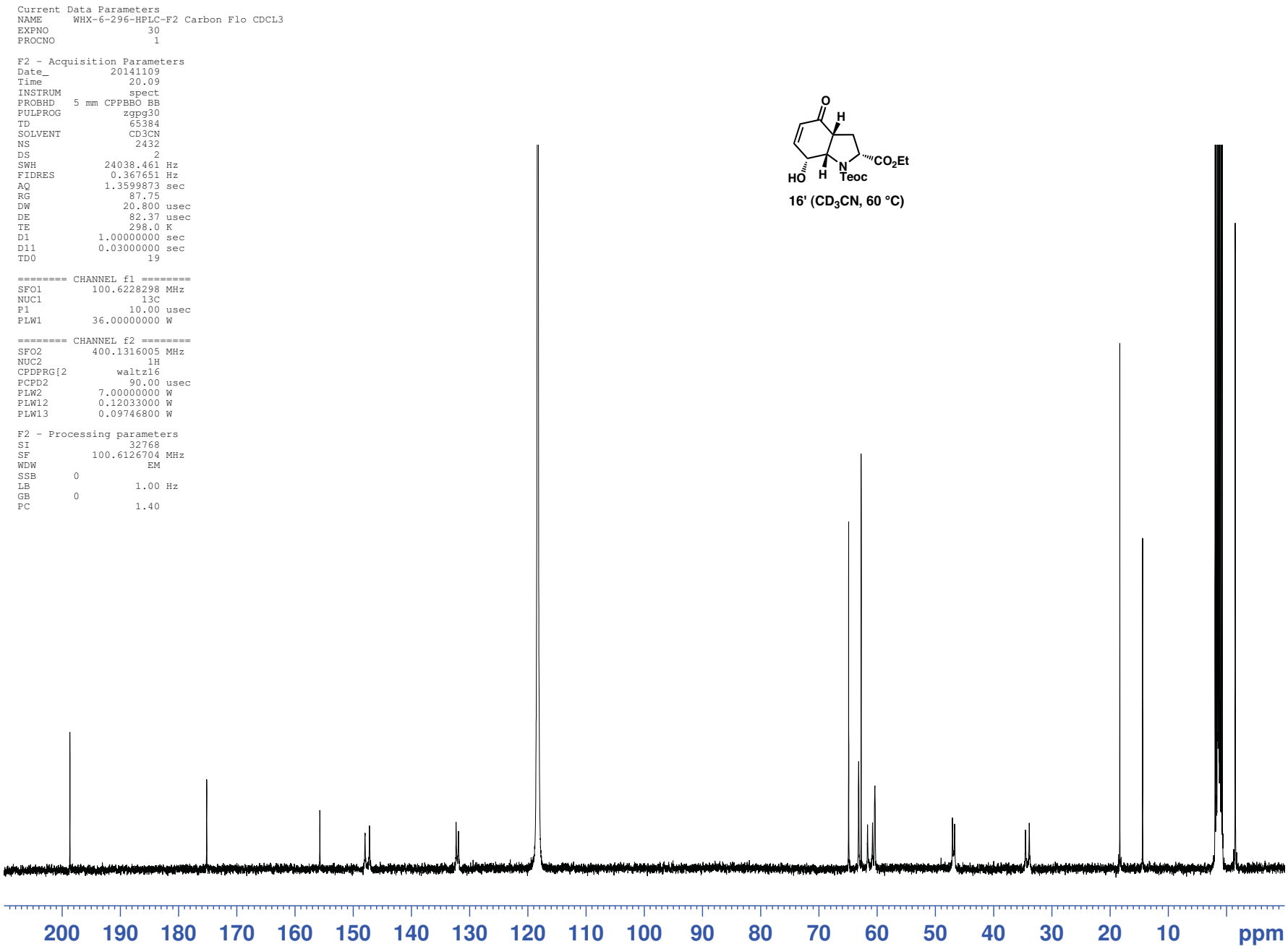

WHX-6-289-F-Flo CDCL3.3.ser
HSQC of 16
f2 (ppm)
f1 (ppm)
S35


WHX-6-289-F-Flo CDCL3.4.ser
HMBC of 16
f2 (ppm)
f1 (ppm)
14, 13
1', 19
16, 11


WHX-6-289-F-Flo CDCL3.5.ser
NOESY of 16
f2 (ppm)
f1 (ppm)
key nOe
key nOe
TMS
CO2Et


WHX-6-296-HPLC-F2_Siena_CD3CN
Sample Name:
WHX-6-296-HPLC-F2_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-6-296-HPLC-F2_Siena_CD3CN
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 1 2015
Sample #5, Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970641 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec
O
H
HO
H
N
Teoc
CO2Et
16'
9
8
7
6
5
4
3
2
1
0
ppm
1.00
0.93
1.06
2.46
4.87
1.02
1.08
0.96
3.15
2.16
9.11


WHX-6-296-HPLC-F2_Siena_CD3CN-60C
Sample Name:
WHX-6-296-HPLC-F2_Siena_CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-6-296-HPLC-F2_Siena_CD3CN-60C
FidFile: WHX-6-296-HPLC-F2-Siena-CD3CN-60C-re
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 1 2015
Temp. 60.0 C / 333.1 K
Operator: hwwang
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 32768
Total time 2 min 1 sec
O
H
HO
H
N
Teoc
CO2Et
16' (CD3CN, 60 °C)
9
8
7
6
5
4
3
2
1
0
ppm
1.00
0.93
1.04
2.11
5.09
1.04
1.08
1.08
3.13
2.14
9.17


Current Data Parameters
NAME WHX-6-296-HPLC-F2 Carbon Flo CDCL3
EXPNO 30
PROCNO 1
F2 - Acquisition Parameters
Date_ 20141109
Time 20.09
INSTRUM spect
PROBHD 5 mm CPPBBO BB
PULPROG zgpg30
TD 65384
SOLVENT CD3CN
NS 2432
DS 2
SWH 24038.461 Hz
FIDRES 0.367651 Hz
AQ 1.3599873 sec
RG 87.75
DW 20.800 usec
DE 82.37 usec
TE 298.0 K
D1 1.00000000 sec
D11 0.03000000 sec
TD0 19
======== CHANNEL f1 ========
SFO1 100.6228298 MHz
NUC1 13C
P1 10.00 usec
PLW1 36.00000000 W
======== CHANNEL f2 ========
SFO2 400.1316005 MHz
NUC2 1H
CPDPRG[2 waltz16
PCPD2 90.00 usec
PLW2 7.00000000 W
PLW12 0.12033000 W
PLW13 0.09746800 W
F2 - Processing parameters
SI 32768
SF 100.6126704 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
O
H
HO
H
N
Teoc
CO2Et
16' (CD3CN, 60 °C)
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

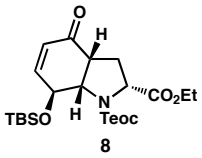
WHX-7-136-F_Siena_CD3CN

Sample Name:
WHX-7-136-F_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-136-F_Siena_CD3CN
FidFile: PROTON01

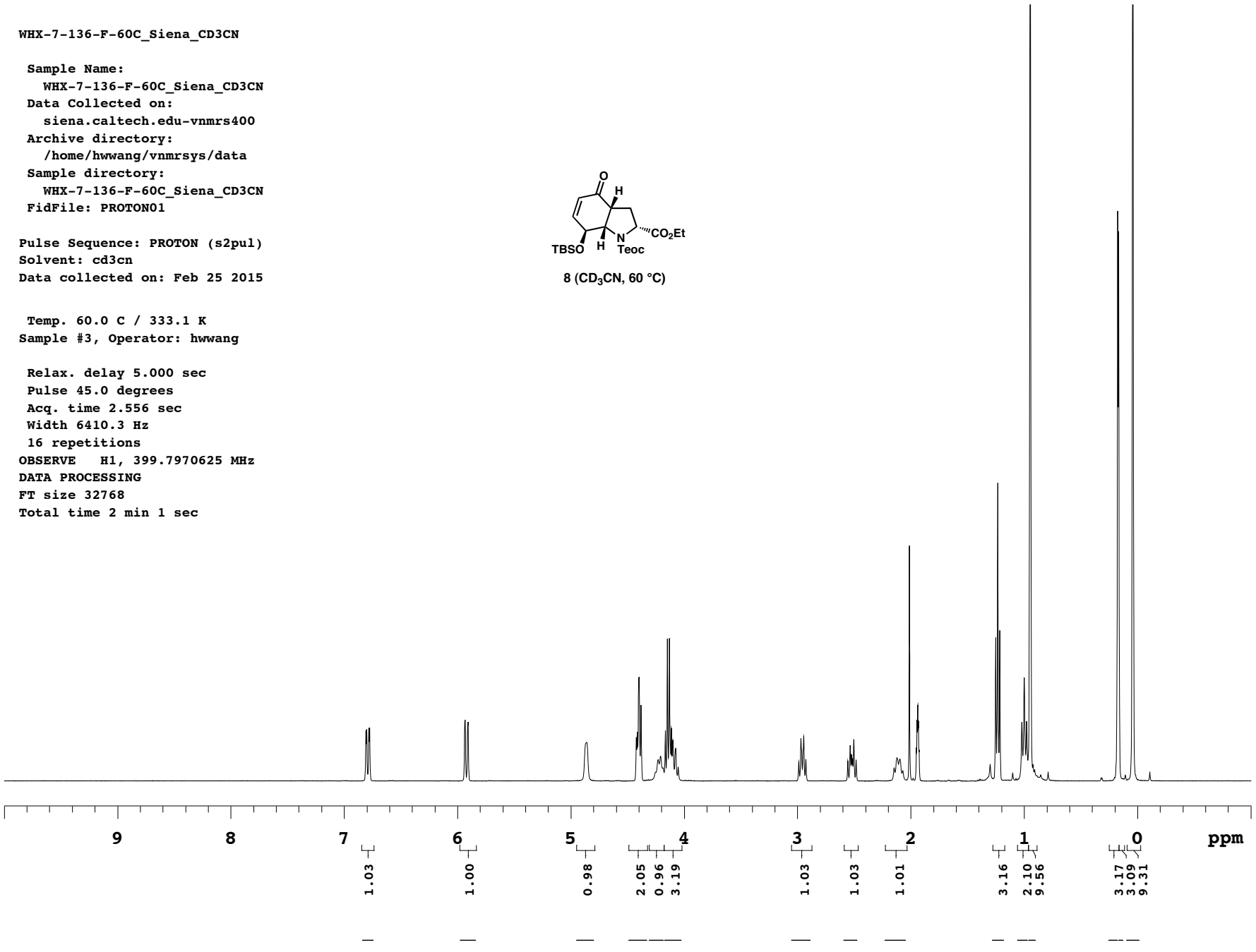
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: Feb 25 2015

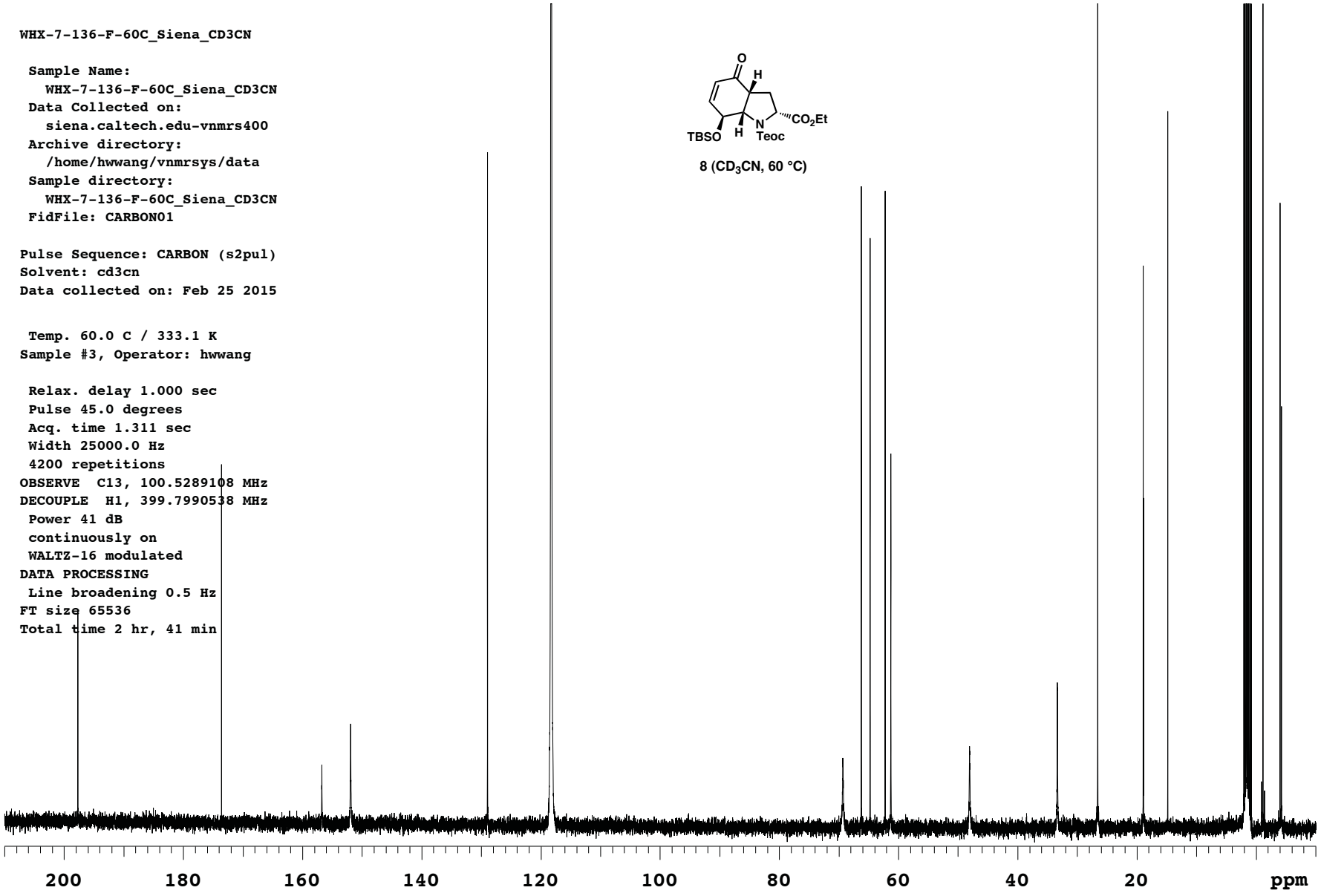
Sample #3, Operator: hwwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec



8


WHX-7-136-F-60C_Siena_CD3CN
Sample Name:
WHX-7-136-F-60C_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-136-F-60C_Siena_CD3CN
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: Feb 25 2015
Temp. 60.0 C / 333.1 K
Sample #3, Operator: hwwang
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970625 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec
O
H
CO2Et
TBSO
H
N
Teoc
8 (CD3CN, 60 °C)
9
8
7
6
5
4
3
2
1
0
ppm
1.03
1.00
0.98
2.05
0.96
3.19
1.03
1.03
1.01
3.16
2.10
9.56
3.17
3.09
9.31


WHX-7-136-F-60C_Siena_CD3CN
Sample Name:
WHX-7-136-F-60C_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-136-F-60C_Siena_CD3CN
FidFile: CARBON01
Pulse Sequence: CARBON (s2pul)
Solvent: cd3cn
Data collected on: Feb 25 2015
Temp. 60.0 C / 333.1 K
Sample #3, Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
4200 repetitions
OBSERVE C13, 100.5289108 MHz
DECOUPLE H1, 399.7990538 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 2 hr, 41 min
O
H
CO2Et
N
TBSO
H
Teoc
8 (CD3CN, 60 °C)
200
180
160
140
120
100
80
60
40
20
ppm

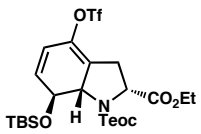
WHX-7-171-F1_Siena_CD3CN

Sample Name:
WHX-7-171-F1_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-171-F1_Siena_CD3CN
FidFile: PROTON01

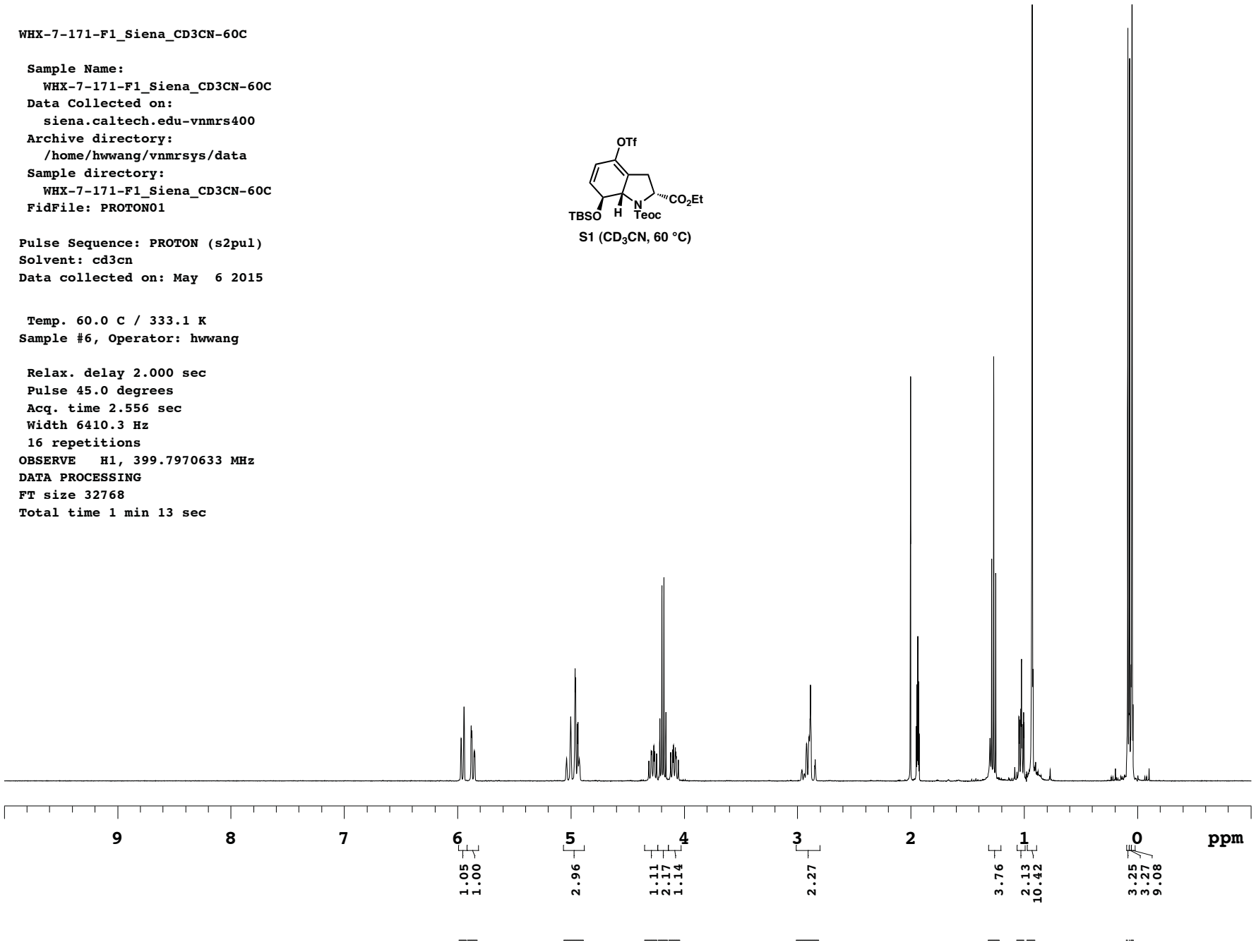
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015

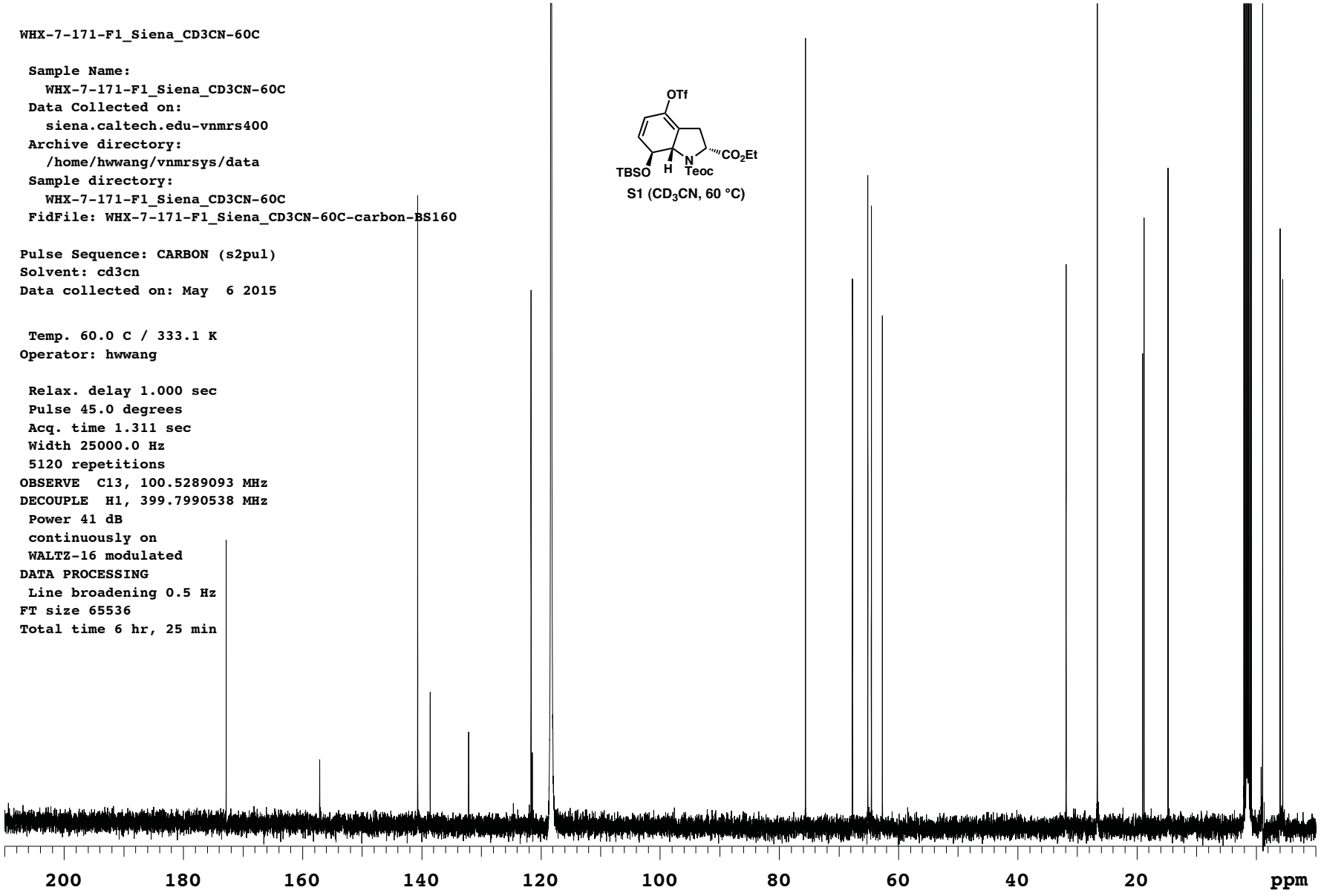
Temp. 25.0 C / 298.1 K
Sample #6, Operator: hwwang

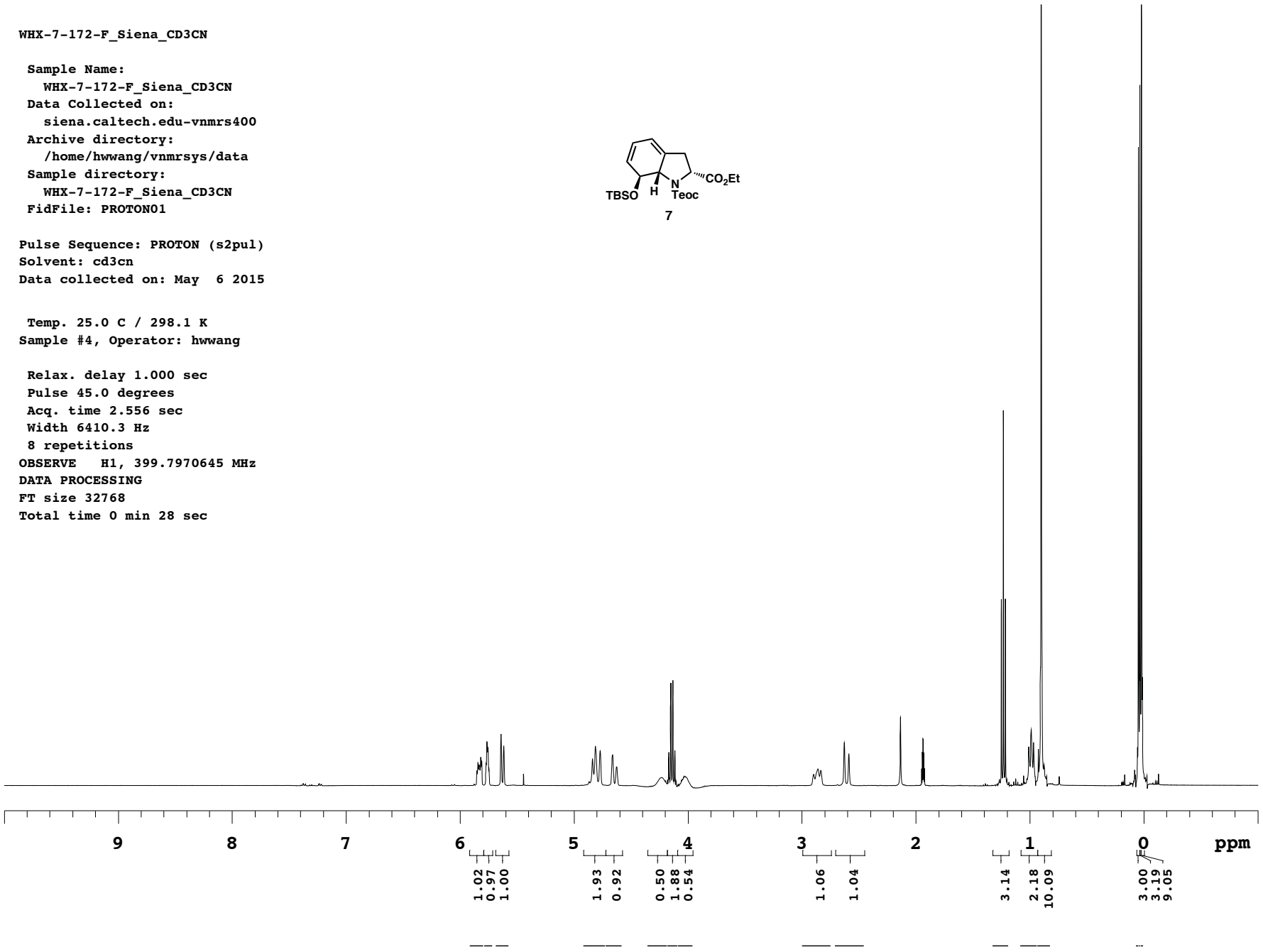
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970641 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec

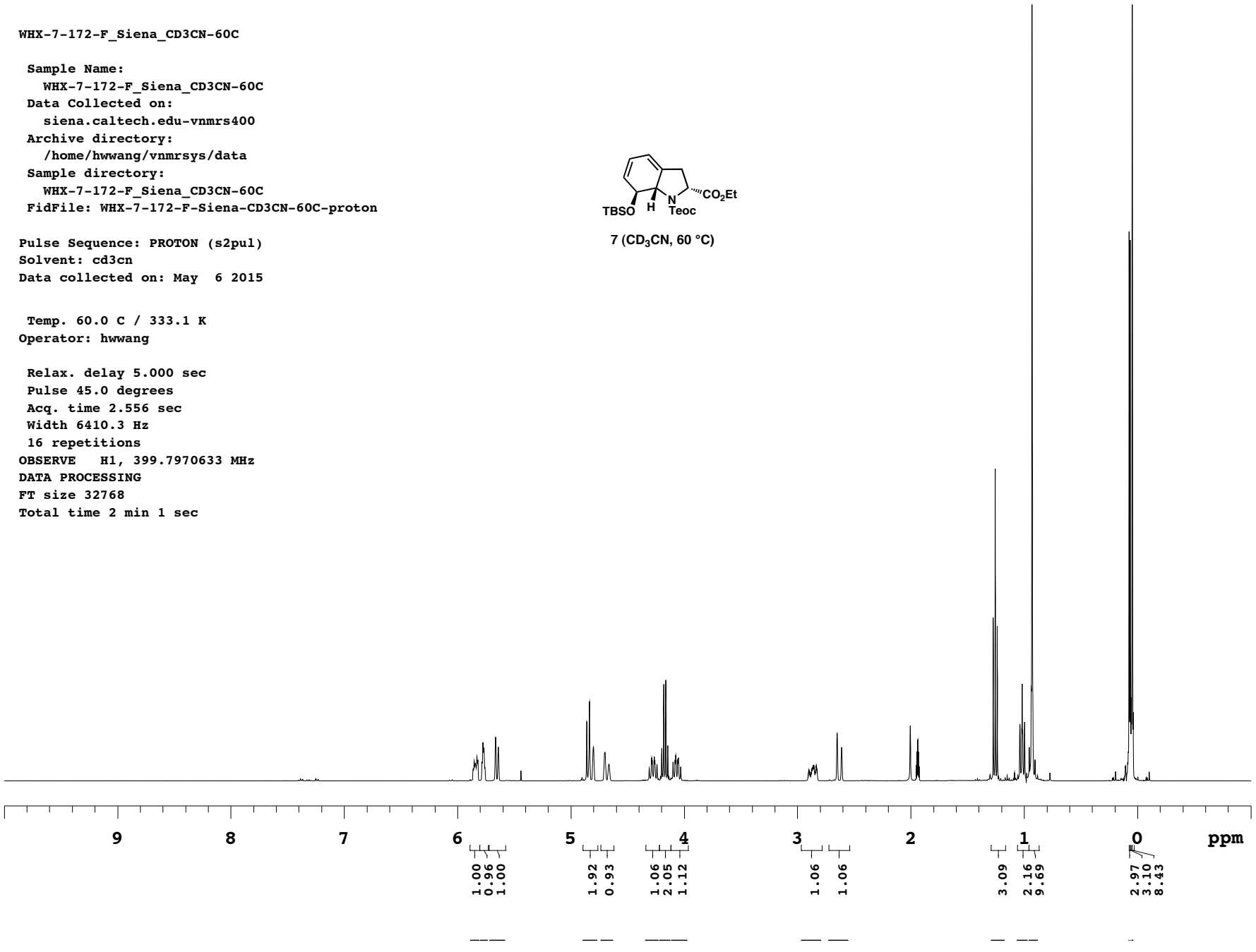


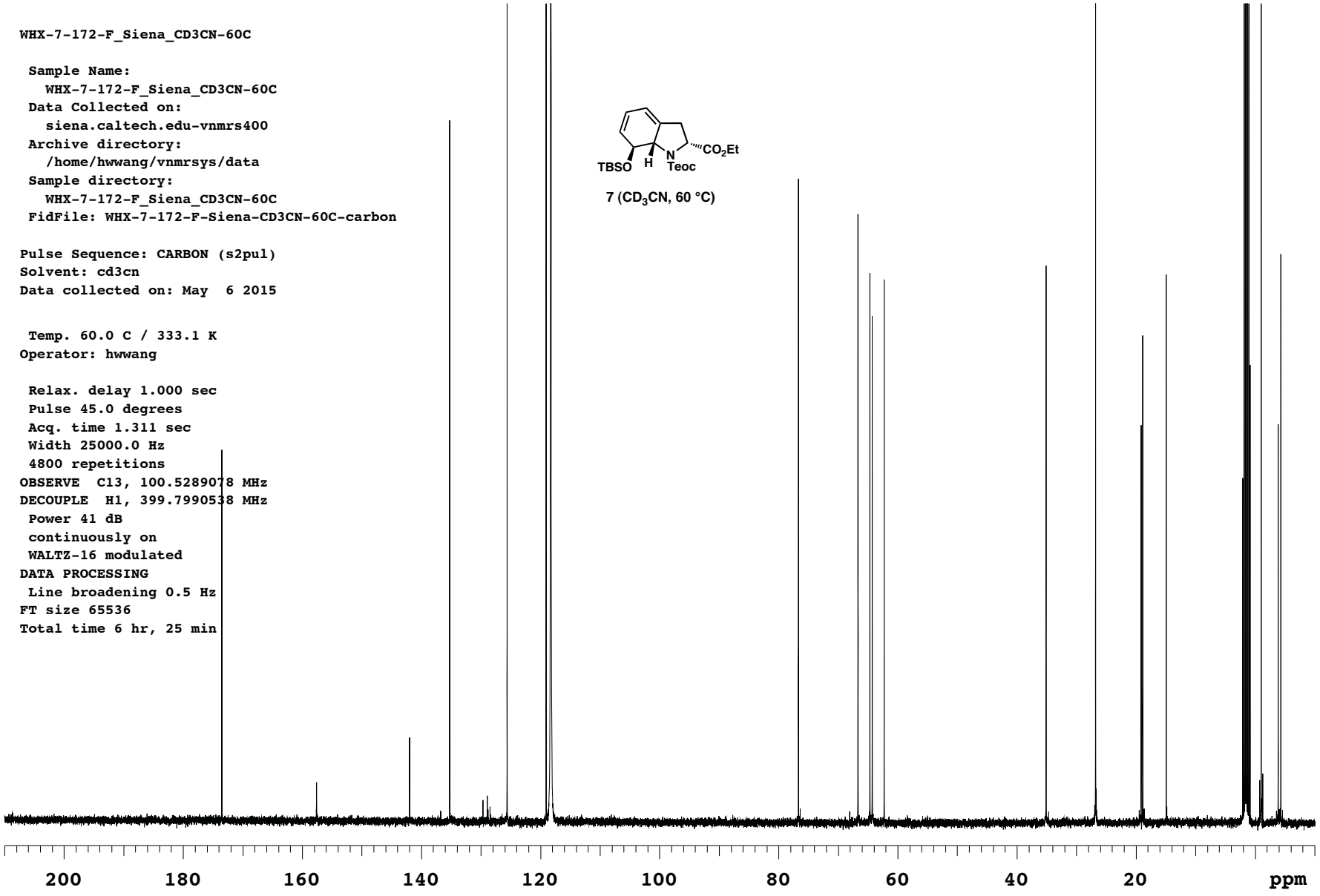
S1

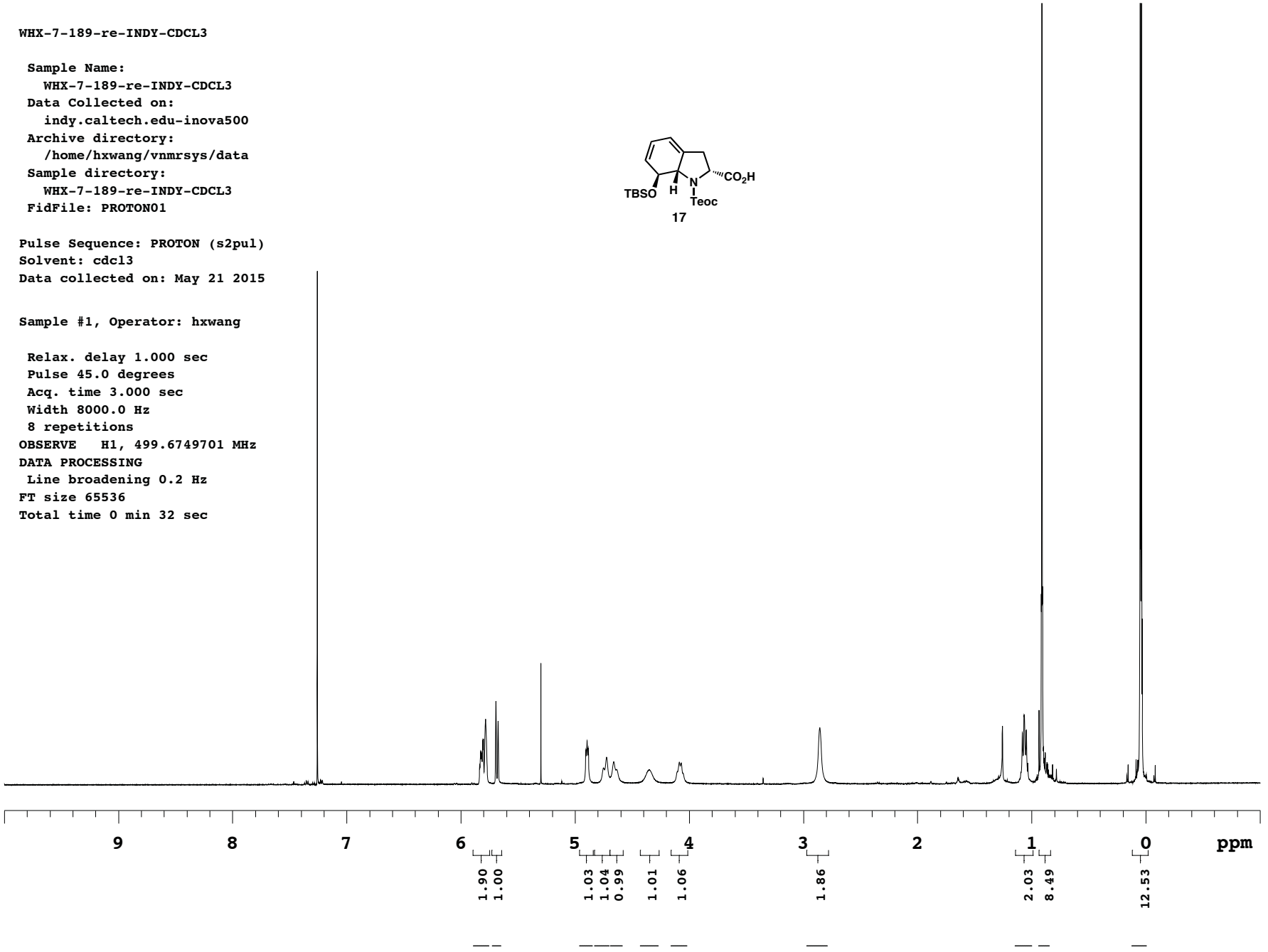

WHX-7-171-F1_Siena_CD3CN-60C
Sample Name:
WHX-7-171-F1_Siena_CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-171-F1_Siena_CD3CN-60C
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015
Temp. 60.0 C / 333.1 K
Sample #6, Operator: hwwang
Relax. delay 2.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
FT size 32768
Total time 1 min 13 sec
OTf
TBSO
H
N
Teoc
CO2Et
S1 (CD3CN, 60 °C)
9
8
7
6
5
4
3
2
1
0
ppm
1.05
1.00
2.96
1.11
2.17
1.14
2.27
3.76
2.13
10.42
3.25
3.27
9.08


WHX-7-171-F1_Siena_CD3CN-60C
Sample Name:
WHX-7-171-F1_Siena_CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-171-F1_Siena_CD3CN-60C
FidFile: WHX-7-171-F1_Siena_CD3CN-60C-carbon-BS160
Pulse Sequence: CARBON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015
Temp. 60.0 C / 333.1 K
Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
5120 repetitions
OBSERVE C13, 100.5289093 MHz
DECOUPLE H1, 399.7990538 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 6 hr, 25 min
OTf
CO2Et
TBSO
H
N
Teoc
S1 (CD3CN, 60 °C)
200
180
160
140
120
100
80
60
40
20
ppm


WHX-7-172-F_Siena_CD3CN
Sample Name:
WHX-7-172-F_Siena_CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-172-F_Siena_CD3CN
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015
Temp. 25.0 C / 298.1 K
Sample #4, Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
8 repetitions
OBSERVE H1, 399.7970645 MHz
DATA PROCESSING
FT size 32768
Total time 0 min 28 sec
TBSO
H
N
Teoc
CO2Et
7
9
8
7
6
5
4
3
2
1
0
ppm
1.02
0.97
1.00
1.93
0.92
0.50
1.88
0.54
1.06
1.04
3.14
2.18
10.09
3.00
3.19
9.05


WHX-7-172-F_Siena_CD3CN-60C
Sample Name:
WHX-7-172-F_Siena_CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-172-F_Siena_CD3CN-60C
FidFile: WHX-7-172-F-Siena-CD3CN-60C-proton
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015
Temp. 60.0 C / 333.1 K
Operator: hwwang
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970633 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec
TBSO
H
N
Teoc
CO2Et
7 (CD3CN, 60 °C)
9
8
7
6
5
4
3
2
1
0
ppm
1.00
0.96
1.00
1.92
0.93
1.06
2.05
1.12
1.06
1.06
3.09
2.16
9.69
2.97
3.10
8.43


WHX-7-172-F_Siena_CD3CN-60C
Sample Name:
WHX-7-172-F_Siena_CD3CN-60C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-172-F_Siena_CD3CN-60C
FidFile: WHX-7-172-F-Siena-CD3CN-60C-carbon
Pulse Sequence: CARBON (s2pul)
Solvent: cd3cn
Data collected on: May 6 2015
Temp. 60.0 C / 333.1 K
Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
4800 repetitions
OBSERVE C13, 100.5289078 MHz
DECOUPLE H1, 399.7990538 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 6 hr, 25 min
TBSO
H
N
Teoc
CO2Et
7 (CD3CN, 60 °C)
200
180
160
140
120
100
80
60
40
20
ppm


WHX-7-189-re-INDY-CDCL3
Sample Name:
WHX-7-189-re-INDY-CDCL3
Data Collected on:
indy.caltech.edu-inova500
Archive directory:
/home/hxwang/vnmrsys/data
Sample directory:
WHX-7-189-re-INDY-CDCL3
FidFile: PROTON01
Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: May 21 2015
Sample #1, Operator: hxwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 3.000 sec
Width 8000.0 Hz
8 repetitions
OBSERVE H1, 499.6749701 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min 32 sec
TBSO
H
N
Teoc
CO2H
17
9
8
7
6
5
4
3
2
1
0
ppm
1.90
1.00
1.03
1.04
0.99
1.01
1.06
1.86
2.03
8.49
12.53

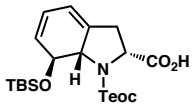
WHX-7-189-F-Siena-CDCL3-45C

Sample Name:
WHX-7-189-F-Siena-CDCL3-45C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-189-F-Siena-CDCL3-45C
FidFile: WHX-7-189-F-Siena-CDCL3-45C-proton

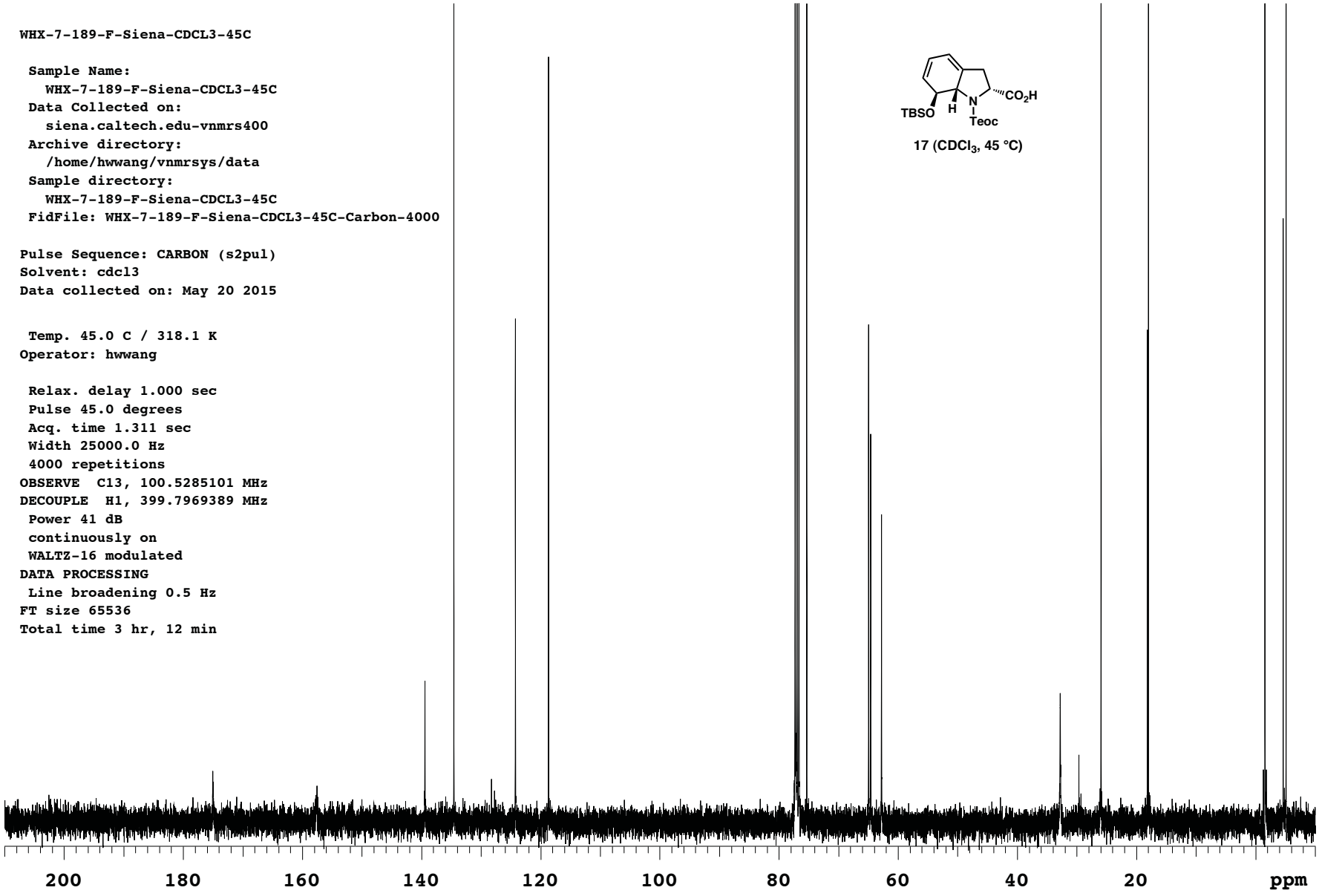
Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: May 20 2015

Temp. 45.0 C / 318.1 K
Operator: hwwang

Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7949397 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec



17 ($CDCl_3$, 45 °C)


WHX-7-189-F-Siena-CDCL3-45C
Sample Name:
WHX-7-189-F-Siena-CDCL3-45C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-189-F-Siena-CDCL3-45C
FidFile: WHX-7-189-F-Siena-CDCL3-45C-Carbon-4000
Pulse Sequence: CARBON (s2pul)
Solvent: cdcl3
Data collected on: May 20 2015
Temp. 45.0 C / 318.1 K
Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
4000 repetitions
OBSERVE C13, 100.5285101 MHz
DECOUPLE H1, 399.7969389 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 3 hr, 12 min
TBSO
H
N
Teoc
CO2H
17 (CDCl3, 45 °C)
200
180
160
140
120
100
80
60
40
20
ppm

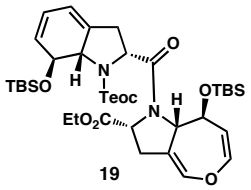
WHX-7-192-F-Siena-CD3CN

Sample Name:
WHX-7-192-F-Siena-CD3CN
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-192-F-Siena-CD3CN
FidFile: PROTON01

Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 23 2015

Temp. 25.0 C / 298.1 K
Sample #4, Operator: hwwang

Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970641 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec



19

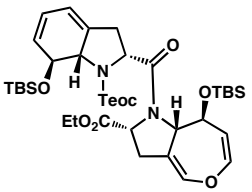
WHX-7-192-F-Siena-CD3CN-50C

Sample Name:
WHX-7-192-F-Siena-CD3CN-50C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-192-F-Siena-CD3CN-50C
FidFile: WHX-7-192-F-Siena-CD3CN-50C-proton

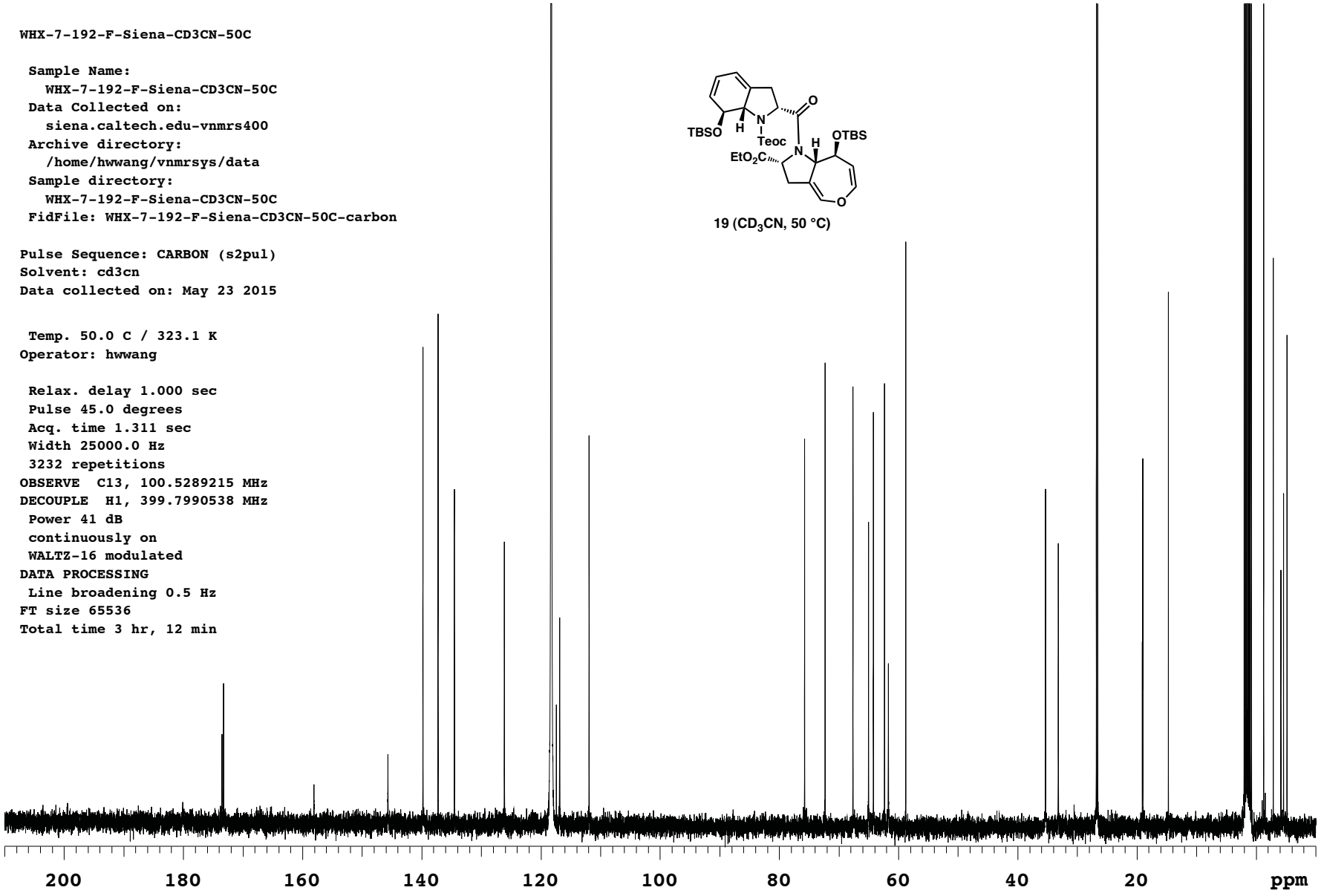
Pulse Sequence: PROTON (s2pul)
Solvent: cd3cn
Data collected on: May 23 2015

Temp. 50.0 C / 323.1 K
Operator: hwwang

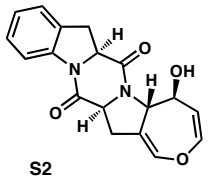
Relax. delay 5.000 sec
Pulse 45.0 degrees
Acq. time 2.556 sec
Width 6410.3 Hz
16 repetitions
OBSERVE H1, 399.7970637 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 1 sec



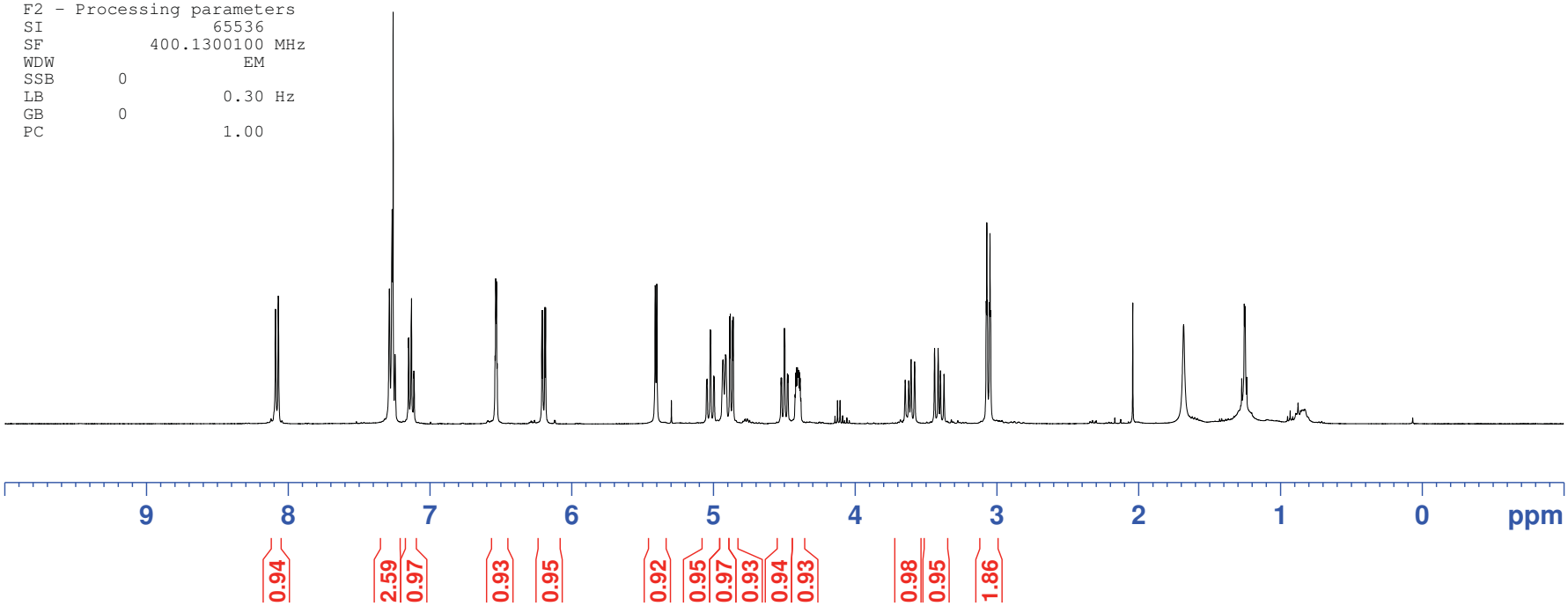
19 (CD_3CN, 50 °C)


WHX-7-192-F-Siena-CD3CN-50C
Sample Name:
WHX-7-192-F-Siena-CD3CN-50C
Data Collected on:
siena.caltech.edu-vnmrs400
Archive directory:
/home/hwwang/vnmrsys/data
Sample directory:
WHX-7-192-F-Siena-CD3CN-50C
FidFile: WHX-7-192-F-Siena-CD3CN-50C-carbon
Pulse Sequence: CARBON (s2pul)
Solvent: cd3cn
Data collected on: May 23 2015
Temp. 50.0 C / 323.1 K
Operator: hwwang
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.311 sec
Width 25000.0 Hz
3232 repetitions
OBSERVE C13, 100.5289215 MHz
DECOUPLE H1, 399.7990538 MHz
Power 41 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 3 hr, 12 min
TBSO
H
N
Teoc
O
EtO2C
N
H
OTBS
O
19 (CD3CN, 50 °C)
200
180
160
140
120
100
80
60
40
20
ppm

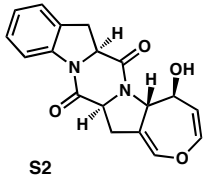
```
Current Data Parameters
NAME      WHX-7-193-F1-Flo-CDCL3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150523
Time                8.48
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH              8012.820 Hz
FIDRES           0.122266 Hz
AQ               4.0894465 sec
RG                 142.81
DW                 62.400 usec
DE                 10.00 usec
TE                 295.0 K
D1            5.00000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                   1H
P1                 11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                 65536
SF           400.1300100 MHz
WDW                   EM
SSB       0
LB                  0.30 Hz
GB        0
PC                  1.00
```



S2

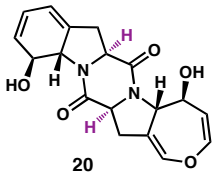


```
Current Data Parameters
NAME      WHX-7-193-F1-Flo-CDCL3
EXPNO                  2
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150523
Time                9.45
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                65536
SOLVENT            CDCl3
NS                 1400
DS                    4
SWH           24038.461 Hz
FIDRES         0.366798 Hz
AQ            1.3631488 sec
RG                37.97
DW               20.800 usec
DE                82.37 usec
TE                294.9 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1        100.6228293 MHz
NUC1                13C
P1                10.00 usec
PLW1        36.00000000 W

======== CHANNEL f2 ========
SFO2        400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2             90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF          100.6127735 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

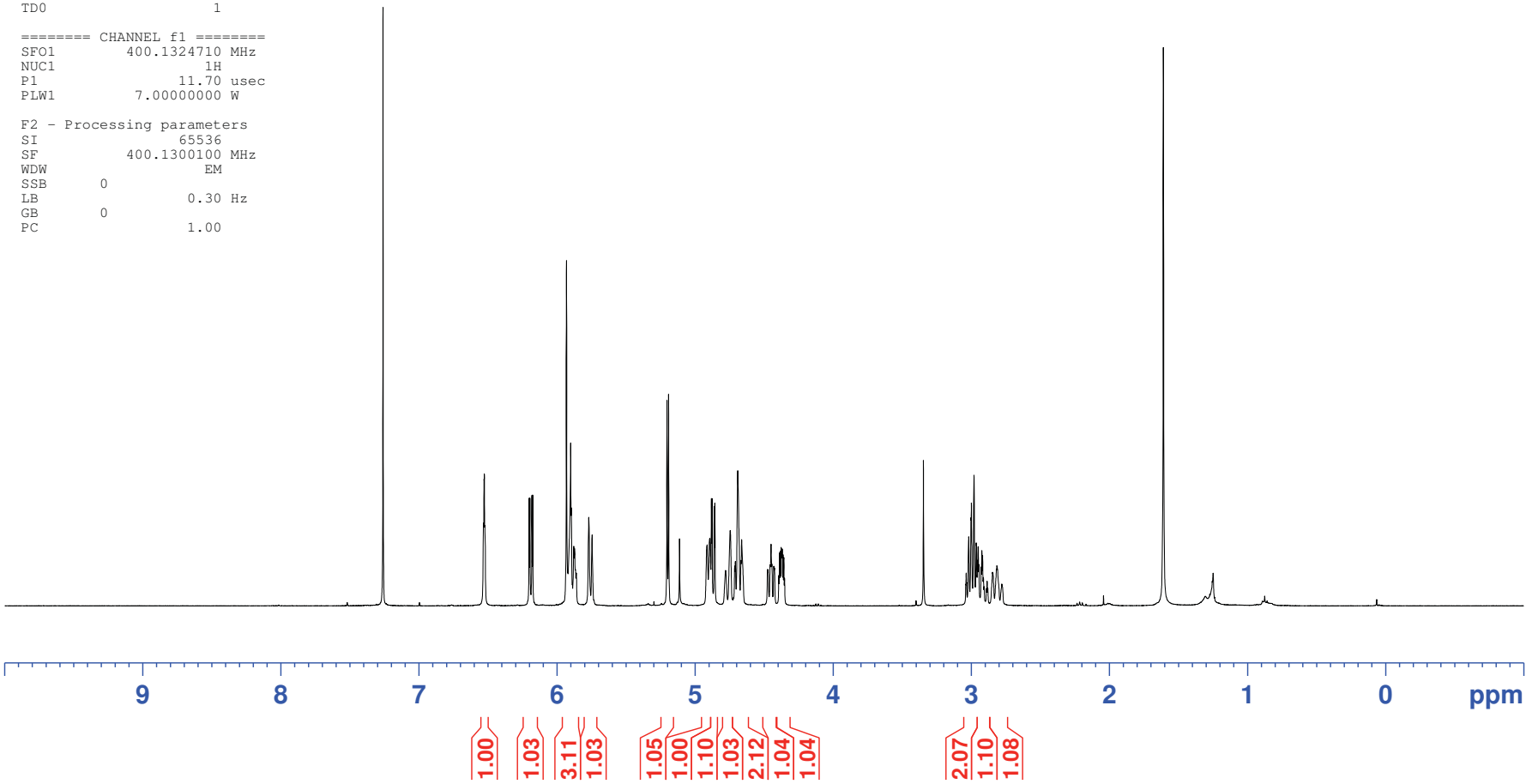


S2

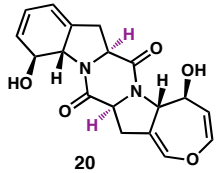
```
Current Data Parameters
NAME      WHX-7-188-F-Chara-Flo-CDCL3
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameters
Date_            20150519
Time                13.02
INSTRUM             spect
PROBHD   5 mm CPPBBO BB
PULPROG              zg30
TD                  65536
SOLVENT             CDCl3
NS                     16
DS                      2
SWH              8012.820 Hz
FIDRES           0.122266 Hz
AQ               4.0894465 sec
RG                  197.44
DW                  62.400 usec
DE                   10.00 usec
TE                   294.9 K
D1            2.00000000 sec
TD0                     1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                   1H
P1                  11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                  65536
SF           400.1300100 MHz
WDW                    EM
SSB       0
LB                  0.30 Hz
GB        0
PC                  1.00
```



20

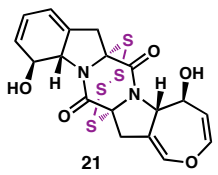


```
Current Data Parameters
NAME     WHX-7-188-F-Chara-Flo-CDCL3
EXPNO                  30
PROCNO                  1

F2 - Acquisition Parameters
Date_           20150519
Time              14.04
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                65384
SOLVENT           CDCl3
NS                 1450
DS                    4
SWH           24038.461 Hz
FIDRES         0.367651 Hz
AQ            1.3599873 sec
RG                72.02
DW               20.800 usec
DE                82.37 usec
TE                295.0 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1        100.6228293 MHz
NUC1                13C
P1                10.00 usec
PLW1        36.00000000 W

======== CHANNEL f2 ========
SFO2        400.1316005 MHz
NUC2                  1H
CPDPRG[2         waltz16
PCPD2             90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                32768
SF          100.6127728 MHz
WDW                EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



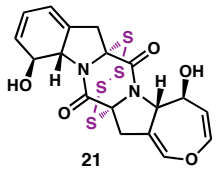
20

```
Current Data Parameters
NAME      WHX-7-194-F3-Flo-CDCL3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150523
Time              23.04
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8012.820 Hz
FIDRES         0.122266 Hz
AQ             4.0894465 sec
RG                197.44
DW                62.400 usec
DE                10.00 usec
TE                295.0 K
D1           5.00000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                1H
P1                11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                65536
SF           400.1300101 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



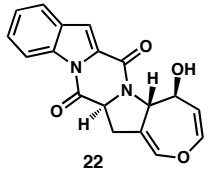
21

```
Current Data Parameters
NAME      WHX-7-194-F3-Flo-CDCL3
EXPNO                 30
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150523
Time               23.13
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                 65384
SOLVENT            CDCl3
NS                  8960
DS                     2
SWH            24038.461 Hz
FIDRES          0.367651 Hz
AQ             1.3599873 sec
RG                 72.02
DW                20.800 usec
DE                82.37 usec
TE                295.0 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                   70

======== CHANNEL f1 ========
SFO1         100.6228298 MHz
NUC1                13C
P1                 10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2              90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6127718 MHz
WDW                  EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

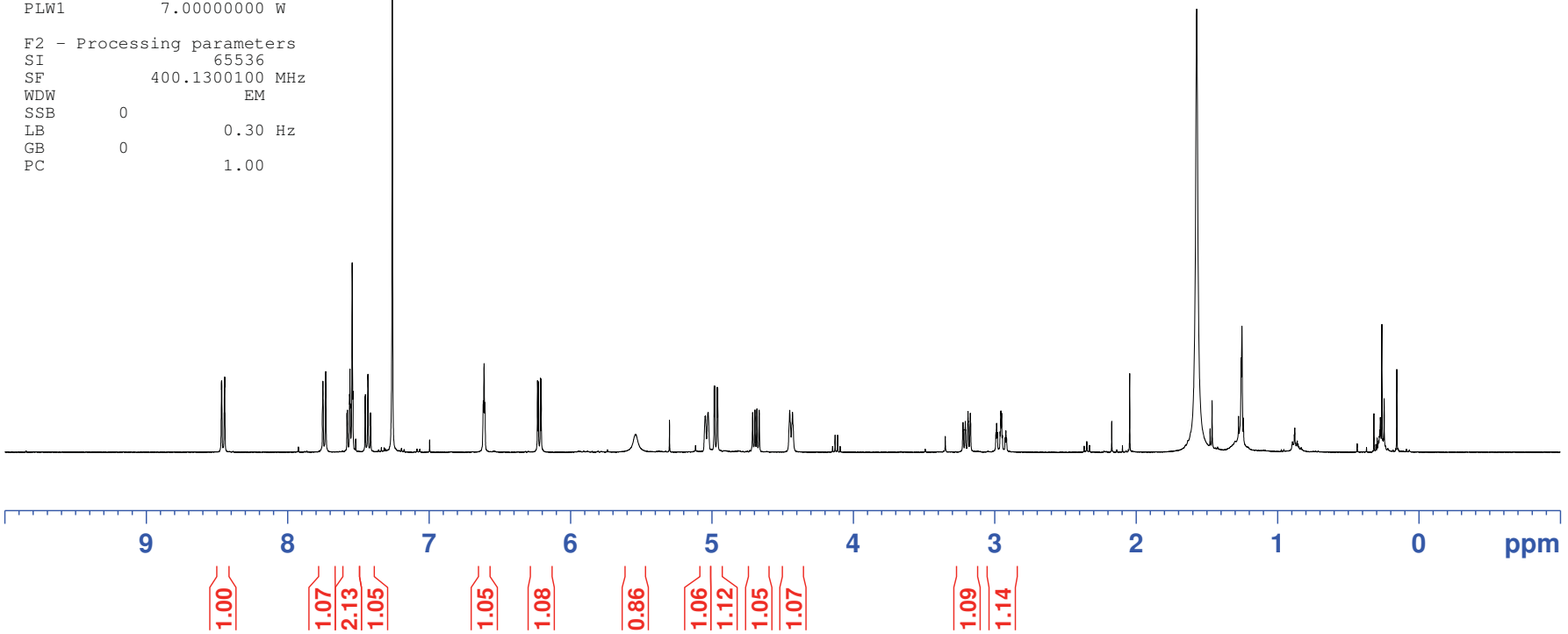


21

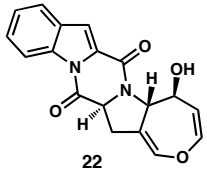
```
Current Data Parameters
NAME      WHX-7-223-F1-Flo-CDCL3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150624
Time              21.05
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8012.820 Hz
FIDRES         0.122266 Hz
AQ            4.0894465 sec
RG               197.44
DW               62.400 usec
DE               10.00 usec
TE               294.9 K
D1           2.00000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1        400.1324710 MHz
NUC1                  1H
P1                11.70 usec
PLW1         7.00000000 W

F2 - Processing parameters
SI                65536
SF          400.1300100 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



22



```
Current Data Parameters
NAME      WHX-7-223-F1-Flo-CDCL3
EXPNO                 10
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150624
Time              23.48
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                65384
SOLVENT           CDCl3
NS                 4000
DS                    4
SWH           24038.461 Hz
FIDRES         0.367651 Hz
AQ            1.3599873 sec
RG                55.48
DW               20.800 usec
DE                82.37 usec
TE                295.0 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1        100.6228293 MHz
NUC1                13C
P1                10.00 usec
PLW1        36.00000000 W

======== CHANNEL f2 ========
SFO2        400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2             90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                32768
SF          100.6127720 MHz
WDW                  EM
SSB      0
LB                1.00 Hz
GB       0
PC                1.40
```



22

WHX-7-195-F-FID-CDCL3

Sample Name:
WHX-7-195-F-FID-CDCL3
Data Collected on:
fid.caltech.edu-inova600
Archive directory:

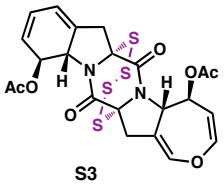
Sample directory:

FidFile: WHX-7-195-F-FID-CDCL3

Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: May 26 2015

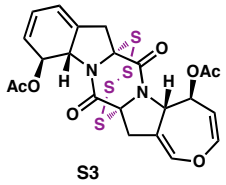
Temp. 25.0 C / 298.1 K
Operator: hxwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.705 sec
Width 9611.9 Hz
64 repetitions
OBSERVE H1, 599.6200960 MHz
DATA PROCESSING
FT size 32768
Total time 2 min 53 sec



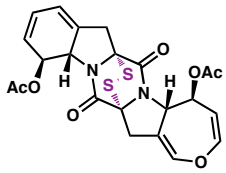
S3

```
Current Data Parameters
NAME      WHX-7-195-F-Flo-CDCL3
EXPNO                    30
PROCNO                    1

F2 - Acquisition Parameters
Date_           20150525
Time               22.08
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG           zgpg30
TD                 65384
SOLVENT            CDCl3
NS                  8960
DS                     2
SWH            24038.461 Hz
FIDRES          0.367651 Hz
AQ             1.3599873 sec
RG                 72.02
DW                20.800 usec
DE                82.37 usec
TE                295.0 K
D1             1.00000000 sec
D11            0.03000000 sec
TD0                   70

======== CHANNEL f1 ========
SFO1         100.6228298 MHz
NUC1                13C
P1                10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2             90.00 usec
PLW2           7.00000000 W
PLW12          0.12033000 W
PLW13          0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6127718 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

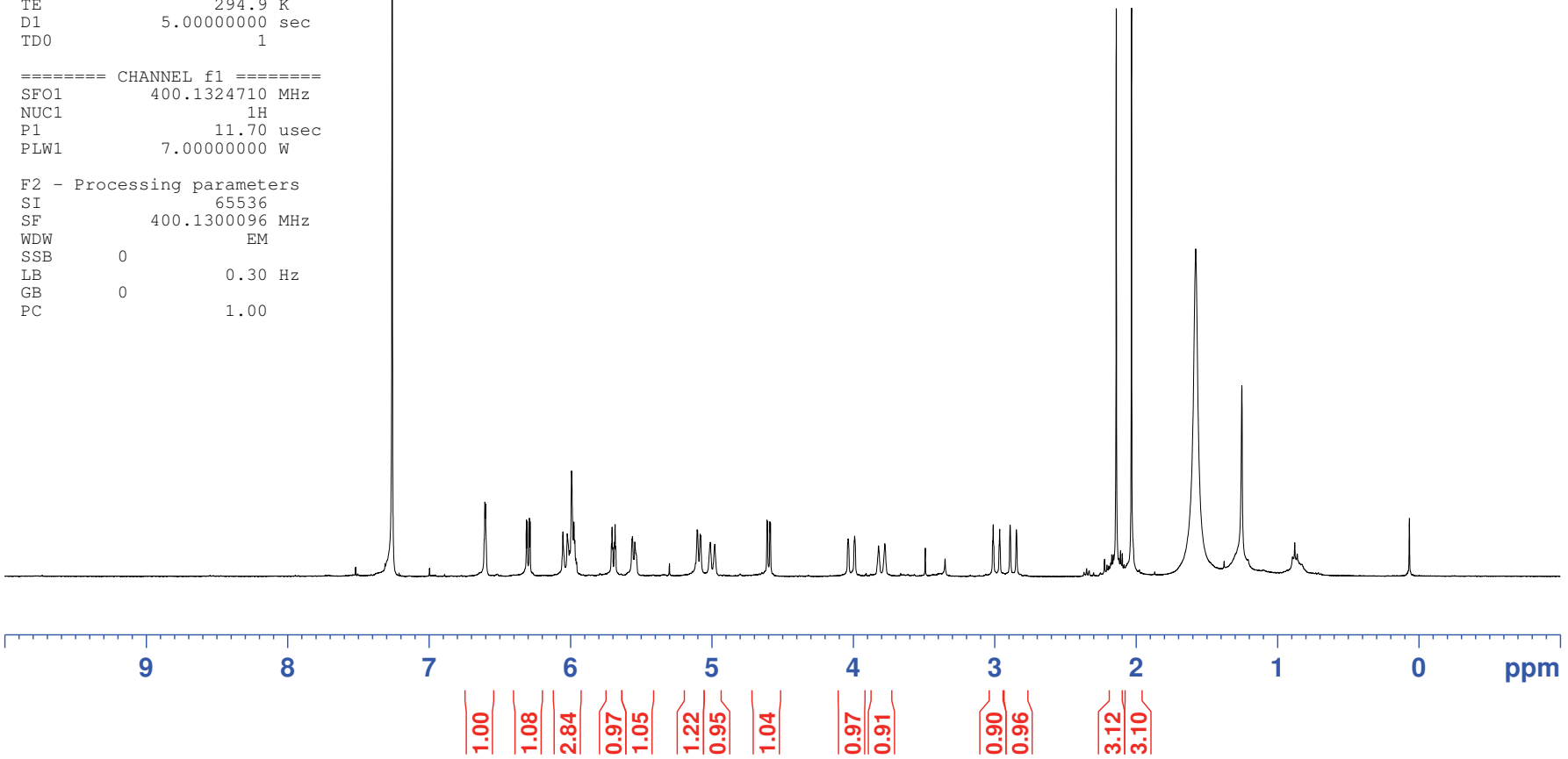


S3

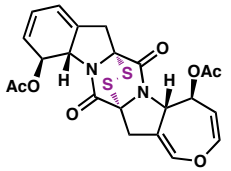
```
Current Data Parameters
NAME      WHX-7-225-F-Flo-CDCL3
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameters
Date_            20150627
Time                0.37
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG             zg30
TD                 65536
SOLVENT            CDC13
NS                    32
DS                     2
SWH             8012.820 Hz
FIDRES          0.122266 Hz
AQ             4.0894465 sec
RG                197.44
DW                62.400 usec
DE                10.00 usec
TE                294.9 K
D1            5.00000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                  1H
P1                 11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                 65536
SF           400.1300096 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```



(–)-acetylapoaranotin (3)



```
Current Data Parameters
NAME      WHX-7-225-F-Flo-CDCL3
EXPNO                    30
PROCNO                    1

F2 - Acquisition Parameters
Date_           20150627
Time                7.24
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG            zgpg30
TD                 65384
SOLVENT            CDCl3
NS                 10000
DS                     4
SWH            24038.461 Hz
FIDRES          0.367651 Hz
AQ             1.3599873 sec
RG                 72.02
DW                20.800 usec
DE                 82.37 usec
TE                 294.9 K
D1            1.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         100.6228293 MHz
NUC1                13C
P1                 10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2              90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6127721 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



(–)-acetylapoaranotin (3)

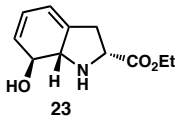
WHX-7-173-F-INDY-CDCL3

Sample Name:
WHX-7-173-F-INDY-CDCL3
Data Collected on:
indy.caltech.edu-inova500
Archive directory:
/home/hxwang/vnmrsys/data
Sample directory:
WHX-7-173-F-INDY-CDCL3
FidFile: PROTON01

Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: May 7 2015

Sample #19, Operator: hxwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 3.000 sec
Width 8000.0 Hz
8 repetitions
OBSERVE H1, 499.6749700 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min 32 sec



23

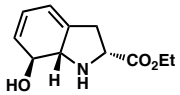
WHX-7-173-F-INDY-CDCL3

Sample Name:
WHX-7-173-F-INDY-CDCL3
Data Collected on:
indy.caltech.edu-inova500
Archive directory:
/home/hxwang/vnmrsys/data
Sample directory:
WHX-7-173-F-INDY-CDCL3
FidFile: CARBON01

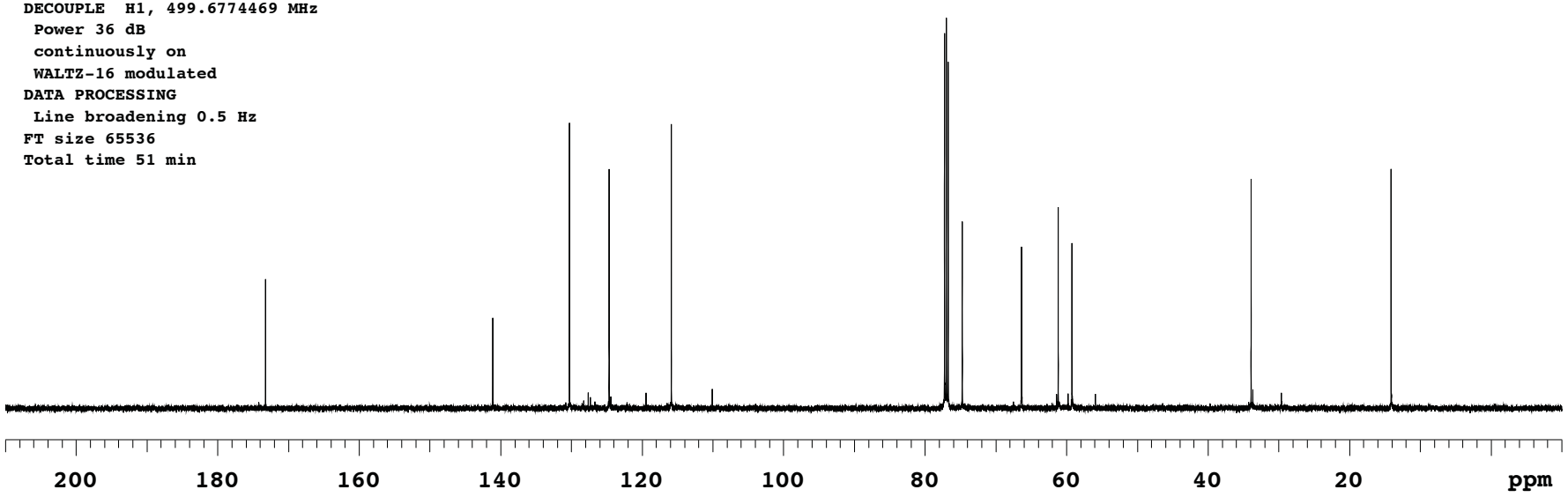
Pulse Sequence: CARBON (s2pul)
Solvent: cdcl3
Data collected on: May 7 2015

Sample #20, Operator: hxwang

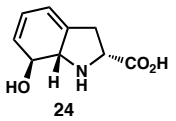
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.042 sec
Width 31446.5 Hz
1500 repetitions
OBSERVE C13, 125.6433729 MHz
DECOUPLE H1, 499.6774469 MHz
Power 36 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 51 min



23

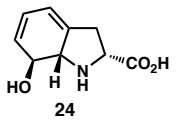


```
Current Data Parameters
NAME      WHX-7-174-HPLC-F-Flo-MeOD
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20150508
Time               19.49
INSTRUM            spect
PROBHD   5 mm CPPBBO BB
PULPROG             zg30
TD                 65536
SOLVENT             MeOD
NS                    16
DS                     2
SWH             8012.820 Hz
FIDRES          0.122266 Hz
AQ              4.0894465 sec
RG                 127.09
DW                62.400 usec
DE                10.00 usec
TE                298.2 K
D1             5.00000000 sec
TD0                    1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                   1H
P1                 11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                 65536
SF            400.1300078 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```



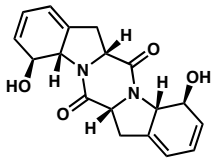
24

```
Current Data Parameters
NAME     WHX-7-174-HPLC-F-Flo-MeOD
EXPNO                 2
PROCNO                1

F2 - Acquisition Parameters
Date_          20150508
Time              20.08
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG          zgpg30
TD                65536
SOLVENT             MeOD
NS                  128
DS                    2
SWH           24038.461 Hz
FIDRES         0.366798 Hz
AQ            1.3631488 sec
RG                 64.2
DW               20.800 usec
DE                82.37 usec
TE                298.2 K
D1           1.00000000 sec
D11          0.03000000 sec
TD0                  11

======== CHANNEL f1 ========
SFO1        100.6228298 MHz
NUC1                13C
P1                10.00 usec
PLW1        36.00000000 W

======== CHANNEL f2 ========
SFO2        400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2             90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                32768
SF          100.6126282 MHz
WDW                  EM
SSB      0
LB                1.00 Hz
GB       0
PC                1.40
```



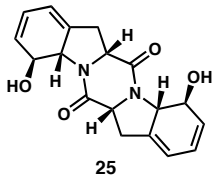
24

```
Current Data Parameters
NAME      WHX-7-175-F-Flo-CDCL3
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameters
Date_           20150510
Time              19.43
INSTRUM           spect
PROBHD   5 mm CPPBBO BB
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8012.820 Hz
FIDRES        0.122266 Hz
AQ            4.0894465 sec
RG               197.44
DW               62.400 usec
DE               10.00 usec
TE               298.1 K
D1           1.00000000 sec
TD0                   1

======== CHANNEL f1 ========
SFO1         400.1324710 MHz
NUC1                 1H
P1                11.70 usec
PLW1          7.00000000 W

F2 - Processing parameters
SI                65536
SF           400.1300097 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



25

```
Current Data Parameters
NAME      WHX-7-175-F-Flo-CDCL3
EXPNO                  30
PROCNO                  1

F2 - Acquisition Parameters
Date_            20150510
Time                21.04
INSTRUM             spect
PROBHD   5 mm CPPBBO BB
PULPROG            zgpg30
TD                  65384
SOLVENT             CDCl3
NS                   2000
DS                      4
SWH             24038.461 Hz
FIDRES           0.367651 Hz
AQ              1.3599873 sec
RG                  78.69
DW                 20.800 usec
DE                 82.37 usec
TE                 298.2 K
D1            1.00000000 sec
D11           0.03000000 sec
TD0                     1

======== CHANNEL f1 ========
SFO1         100.6228293 MHz
NUC1                13C
P1                 10.00 usec
PLW1         36.00000000 W

======== CHANNEL f2 ========
SFO2         400.1316005 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2              90.00 usec
PLW2          7.00000000 W
PLW12         0.12033000 W
PLW13         0.09746800 W

F2 - Processing parameters
SI                 32768
SF           100.6127706 MHz
WDW                  EM
SSB       0
LB                  1.00 Hz
GB        0
PC                  1.40
```



25

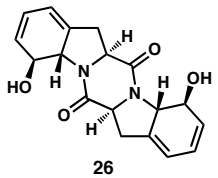
WHX-7-180-F-INDY-CDCL3

Sample Name:
WHX-7-180-F-INDY-CDCL3
Data Collected on:
indy.caltech.edu-inova500
Archive directory:
/home/hxwang/vnmrsys/data
Sample directory:
WHX-7-180-F-INDY-CDCL3
FidFile: PROTON01

Pulse Sequence: PROTON (s2pul)
Solvent: cdcl3
Data collected on: May 12 2015

Sample #47, Operator: hxwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 3.000 sec
Width 8000.0 Hz
8 repetitions
OBSERVE H1, 499.6749675 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min 32 sec



26

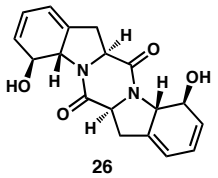
WHX-7-180-F-Charact-INDY-CDCL3

Sample Name:
WHX-7-180-F-Charact-INDY-CDCL3
Data Collected on:
indy.caltech.edu-inova500
Archive directory:
/home/hxwang/vnmrsys/data
Sample directory:
WHX-7-180-F-Charact-INDY-CDCL3
FidFile: CARBON01

Pulse Sequence: CARBON (s2pul)
Solvent: cdcl3
Data collected on: May 12 2015

Sample #49, Operator: hxwang

Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.042 sec
Width 31446.5 Hz
5760 repetitions
OBSERVE C13, 125.6433700 MHz
DECOUPLE H1, 499.6774469 MHz
Power 36 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 0.5 Hz
FT size 65536
Total time 3 hr, 16 min



26